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# JOURNAL OF PALEONTOLOGY

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## APPLIED MICROPALEONTOLOGY IN COASTAL ECUADOR


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ABSTRACT—The Tertiary microfaunas of western Ecuador range in age from lower Middle Eocene to uppermost Miocene. In both regional and local correlation the pelagic Foraminifera are favored as time-markers, because their distribution was little affected by facies variation, and the paper includes a discussion of 25 species of limited range. On empirical grounds a limited number of benthonic Foraminifera appear to be useful time-markers, and 27 species or species-groups are discussed in this respect. The larger Foraminifera are important in dating reefal facies. Radiolaria can be used in local zonation but little systematic work has been devoted to this order. The existence is shown in the Tertiary sediments of five facies-types, four of which are well known in a regional sense (neritic, sublittoral, reefal and brackish). The fifth is a tuffaceous radiolarian facies and evidence is given for considering it as marking a cool marine province along the courses of ex-polar currents which affected the Pacific coast of America but not the Caribbean region. It is demonstrated that the Middle Oligocene of the molluscan time-scale based on Ecuadorean-Peruvian faunas is equivalent to the Upper Eocene of the foraminiferal time-scale as generally accepted in the Caribbean region. This anomaly needs careful recognition as it has already led to faulty correlations in Colombia and Venezuela.


### INTRODUCTION

HANS E. THALMANN (1945) recently listed the papers published on micropaleontologic studies in Ecuador. This list can be amplified by inclusion of more recent papers by Thalmann (1946-a, -b), Stainforth and Stevenson (1946) and Cushman and Stainforth (1946). The literature so far published, particularly on the smaller Foraminifera, has been devoted mainly to descriptions of species and assemblages with little emphasis on their significance in regional or local zonation. An exception is Thalmann's summary of the known Upper Cretaceous foraminiferal faunas (1946-a) but there is no comparable treatment of the Tertiary assemblages. To fill the gap this paper is presented in summary form, in the hope that more detailed studies may be published later. The Tertiary beds of coastal Ecuador belong largely to the Caribbean province, hence paleogeographic studies of the central American region cannot be considered complete without due attention to the depositional history of this country.

The findings expressed below are the result of studies by members of the paleontologic staff of the International Ecuadorean Petroleum Company during the past five or six years. The greatest impetus to this re-

search was given by H. E. Thalmann, in collaboration with D. L. Frizzell, F. Putlitz, F. V. Stevenson and B. Stone. This group of workers completed the paleontologic reconnaissance of the whole coastal belt. The writer, with the able assistance of F. V. Stevenson and A. Martinez, has been solely responsible for a general revision of the initial work and for some detailed zonation and facies-analysis necessary for paleogeographic reconstructions. D. L. Frizzell reviewed some of the assemblages of larger Foraminifera and applied his determinations to correlation between Ecuador and northern Peru. H. E. Thalmann, A. Martinez and the writer have made cursory studies of additional orbitoid assemblages, but knowledge of the larger Foraminifera of Ecuador is still incomplete. Laboratory studies have been confidently based on a fine series of field-stratigraphic surveys by the geologists of International Ecuadorean Petroleum Co., and the writer is personally indebted to J. M. Browning, D. H. Elliott, K. F. Huff, J. G. Marks, L. A. Smith, P. B. Taylor and M. D. Williams for many useful discussions of field relationships. C. A. Durham, and later L. A. Smith, as Chief Geologist in Guayaquil and R. L. Milner, Chief Subsurface Geologist, have also assisted in relating the paleontology to lithostratigraphy. Stratigraphic details of the Santa Elena peninsula have been discussed freely with R. Walls of the Anglo-Ecuadorean Oil Co. Ltd. and P. Spens of Ecuador Oilfields Ltd. C. D. Redmond supplied much valuable unpublished information on foraminiferal ranges in Colombia and P. J. Bermudez furnished similar information for Cuba. B. Stone gave the writer access to his collection of topotype material and made helpful comments on specific determinations. Permission to publish this paper was given by the directorate of the International Ecuadorean Petroleum Company.

The plates were made from pencil drawings by Sres. Manuel Alban and Ramon Neira of Negritos, Peru, whose services were made available through the courtesy of Benton Stone. The specimens figured were chosen from such Ecuadorean residues as were available during the writer's short stay in Negritos. The figured specimens will be deposited in the files of the Cushman Laboratory.

Grateful acknowledgment is here expressed to all these persons for assistance received and for information and opinions incorporated in this paper, although the writer takes full responsibility for the correctness of both factual and inferential statements.

## AGE-SIGNIFICANT FORAMINIFERA

In Ecuador, as in other parts of tropical America, it has proved essential to recognize that similarity or even identity of fossil faunas may indicate only similarity of facies, not necessarily similarity of age. To eliminate confusion arising from such causes, emphasis in developing a regionally applicable foraminiferal zonation has been placed on species restricted to certain levels irrespective of facies. Such Foraminifera fall into two principal groups, the pelagic forms and those benthonic genera which show gradual evolutionary development throughout an appreciable range of time.

### PELAGIC SPECIES

The value of pelagic species lies in their wide lateral distribution consequent upon their drifting mode of life. As they died these organisms sank and eventually became part of the fossil fauna of the underlying seafloor, whether the local facies happened to be neritic, littoral, lagoonal, reefal, or of some other type. In the two principal families of pelagic Foraminifera, the Globigerinidae and the Globorotaliidae, the successive advent and extinction of species in Tertiary time is so spaced as to facilitate the erection of a practicable zonation based on their life-ranges. The truly regional value of this zonation is clearly shown by the almost precisely parallel distribution of species in the Middle Tertiary of Ecuador, on the extreme west of northern South America, and of Trinidad on the eastern extremity. In the list which follows, the pelagic Foraminifera most valuable in the zonation of the Ecuador Tertiary are described in approximately their chronologic order, with notes on their recorded distribution elsewhere. The age-terms given are equivalent to the Tertiary subdivisions generally accepted

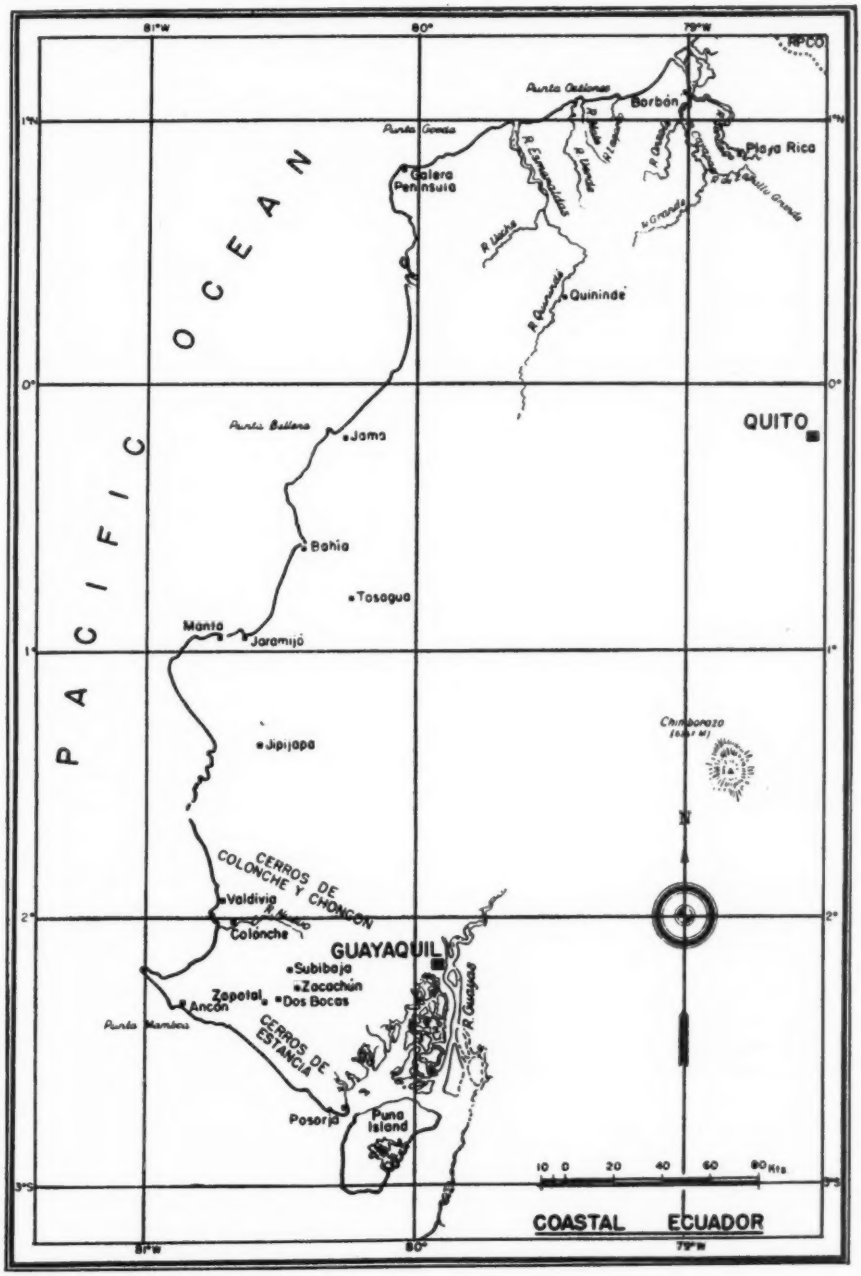


FIG. 1—Outline map of coastal Ecuador showing localities mentioned in the text.

by micropaleontologists in northern South America and the Antilles. The correctness of the majority of the species-names used below has been checked by comparing specimens with topotype or plesiotype material from tropical American localities. Identifications based only on figures and descriptions in the literature are marked with query signs. In systematic order the pelagic species discussed are:

Order FORAMINIFERA
Family GLOBIGERINIDAE
Subfamily GLOBIGERININAE
Genus *Globigerina*
Species *G. aff. bulloides* (p. 118, Pl. 25, figs. 14–18)
*G. cf. concinna* (p. 118, Pl. 25, figs. 19–21)
*G. danvillensis* (p. 117, Pl. 25, figs. 24, 25)
*G. digitata* (p. 123, Pl. 25, figs. 22, 23)
*G. dissimilis* (p. 119, Pl. 25, figs. 29–31)
*G. "triloculinoides"* (p. 117, Pl. 25, figs. 32, 33)
*G. venezuelana* (p. 119, Pl. 25, figs. 26–28)
*G. wilsoni* (?) (p. 117, Pl. 26, figs. 1–3)
Genus *Globigerinoides*
Species *G. conglobata* (p. 121, Pl. 26, figs. 4)
*G. rubra* (p. 122, Pl. 26, figs. 11, 12)
*G. sacculifera* (p. 122, Pl. 26, figs. 7–9)
*G. triloba* (?) (p. 122, Pl. 26, figs. 5, 6)
*G. sp. indet.* (p. 123, Pl. 26, figs. 13–15)
Genus *Globigerinatella*
Species *G. insueta* (p. 120, Pl. 26, figs. 16, 17)
Genus *Globigerinella*
Species *G. aequilateralis* (p. 122, Pl. 26, figs. 10)
Genus *Hastigerinella*
Species *H. eocenica* (p. 116, Pl. 26, figs. 18, 19)
Subfamily PULLENIATININAE
Genus *Pulleniatina*
Species *P. obliquiloculata* (p. 125, Pl. 26, figs. 21–23)
Genus *Sphaeroidinella*
Species *S. dehiscens* (p. 124, Pl. 26, fig. 20)
Subfamily CANDEININAE
Genus *Candorbulina*
Species *C. universa* (p. 123, Pl. 26, fig. 33)
Family GLOBOROTALIIDAE
Genus *Globorotalia*
Species *G. barissanensis* (p. 120, Pl. 26, figs. 24–26)
*G. canariensis* (p. 123, Pl. 26, figs. 30–32)
*G. centralis* (p. 118, Pl. 26, figs. 27–29)
*G. menardii* (p. 124, Pl. 26, figs. 36, 37)
*G. menardii fijiensis* (p. 125, Pl. 26, figs. 38, 39)
*G. menardii multicamerata* (?) (p. 125)
*G. praemenardii* (p. 121, Pl. 26, figs. 34, 35)

HASTIGERINELLA EOCENICA Nuttall
Plate 26, figures 18, 19

*Hastigerinella eocenica* NUTTALL, 1928, Jour. Paleontology, vol. 2, p. 376, pl. 50, figs. 9–11.

Initial portion a low trochoid, later portion planispiral. First adult chambers globose but after the third or fourth showing radial prolongation which becomes progressively more pronounced. In washed residue material this species is most often repre-

sented by individual adult chambers.

This species was originally described from the Upper Eocene of Mexico and later records include the Eocene (Middle and ? Upper) of Trinidad (Cushman 1930, p. 18, pl. 3, figs. 6, 7; Renz 1942, p. 537) and the Eocene of California (Church 1931, p. 206, pl. B, fig. 8; Clark and Campbell 1942, p. 8). The form recorded under this name from the Upper Oligocene of Trinidad is a variety smaller than the Eocene specimens (Cushman and Stainforth 1945, p. 69, pl. 13, fig. 11). Thalmann (1942-a, pp. 14, 15) reported a record by Hugues of abundant *Hastigerinella* in the Eocene of El Alto and Lobitos in Peru, but questioned this unfigured reference because it is unusual for *Hastigerinella* to be a dominant genus. The Ecuadorean occurrence supports Hugues' identification, and there is evidence that the genus thrived in cold waters unfavorable to other Foraminifera. Benton Stone (private communication) confirms that *Hastigerinella* occurs in the Eocene of N. Peru, where *Hantkenina* is exceedingly scarce. In a private communication C. D. Redmond states that *H. eocenica* occurs in the Middle and Upper Eocene of Colombia. In Ecuador the species is restricted to the late Middle and the Upper Eocene and is commonest in tuffaceous shales which contain abundant Radiolaria but usually only sparse Foraminifera. This species is almost absent in the normal neritic and reefal facies of the younger Eocene. A more trochoid species with attenuated pear-shaped chambers appears in the early Oligocene.

### GLOBIGERINA DANVILLENSIS Howe and Wallace
### Plate 25, figures 24, 25

*Globigerina danvillensis* HOWE and WALLACE, 1932, Louisiana Dept. Conser., Geol. Bull. no. 2, p. 74, pl. 10, fig. 9.

General shape a low-spired quadrate trochoid, chambers mildly inflated, the most characteristic feature being the hispid or spinulose shell-surface.

This species was first described from the Jackson Eocene of Louisiana and it was later recorded from the Jackson of Mississippi (Bergquist 1942, p. 95, pl. 9, figs. 24, 25). A very similar form occurs in the Upper Eocene of Trinidad, and it is probably related to *G. topilensis* from the Upper Eocene of Mexico (Cushman 1925, p. 7, pl. 1, fig. 9). In private communications C. D. Redmond states that he has tentatively identified a species from the Upper Eocene of Colombia as *G. danvillensis*, and B. Stone mentions similar forms in the Upper Eocene of northern Peru. In Ecuador this species is confined to Middle and Upper Eocene beds.

### GLOBIGERINA WILSONI (?) Cole 1927
### Plate 26, figures 1–3

*Globigerina wilsoni* COLE, 1927, Bull. Am. Paleontology, vol. 14, no. 51, p. 34, pl. 4, figs. 8, 9.

General form a low trochoid, in larger specimens approaching nautiloid symmetry with only a faint trochoid bias. Dorsal side flat or depressed, early chambers not clearly discernible. Four chambers to a coil. Aperture crescent-shaped, at the base of final chamber, embracing the inner coil from the umbilicus up to and sometimes beyond the periphery.

Except for the type reference from the Eocene, probably Upper Claiborne of Mexico, this species does not seem to have received mention in the literature. Possibly it has been confused with the older *G. pseudo-bulloides* Plummer. In Ecuador it is commonest in the late Middle and Upper Eocene but ranges into the early Oligocene. Frequently this species and *Hastigerinella eocenica* are the only Foraminifera in Radiolaria-rich shales, but *G. wilsoni* is equally plentiful in normal neritic facies of the same age.

### GLOBIGERINA TRILOCULINOIDES (?) Beck, not Plummer
### Plate 25, figures 32, 33

*Globigerina triloculinoides*, BECK, 1943, Jour. Paleontology, vol. 17, no. 6, p. 609, pl. 108, figs. 2, 3.

A low trochoid species, coiling actually quadrate but appearing trigonal because each chamber is approximately double the size of the previous one, and the third from last is inconspicuous, almost invisible in ventral aspect. Early chambers form a low spire with indistinct sutures, but the adult chambers are well inflated and separated by depressed sutures. In ventral aspect the inner margin of the final chamber extends diametrically across the test, concealing a

simple aperture opening into the umbilicus.

This form differs aperturally from the Upper Cretaceous *G. triloculinoides* (Plummer 1926, p. 134, pl. 8, fig. 10; see also Galloway 1931, p. 348, pl. 39, fig. 11). It seems closer to the species first figured by Beck (*loc. cit.*) from the Eocene Cowlitz of Washington and later recorded from the Eo-Oligocene Bastendorf of Oregon (Detling 1946, p. 359, pl. 51, fig. 2). A very similar form has been recorded as *Globigerina* sp. B from the Jackson Eocene of Louisiana and Mississippi (Howe and Wallace 1932, p. 75, pl. 10, fig. 5; Bergquist 1942, p. 95, pl 9, figs. 20, 21, 29, 30). In Ecuador this species occurs in neritic assemblages of Upper Eocene and basal Oligocene age.

GLOBIGERINA aff. BULLOIDES d'Orbigny
Plate 25, figures 14–18

In Ecuador there are two forms which fall within the general usage of this name, which has been so abused as to have little value. One of these is a low trochoid of globose chambers, usually four but sometimes five to a coil. The aperture is a simple circular opening into the umbilicus and carries no lip. There is a faint similarity to *G.* cf. *concinna* but the coiling is less precise and the rate of increase of chamber-size is distinctly greater, their diameters tripling approximately every fourth chamber. This form is close to *G. diplostoma* which Cushman has treated as a varietal form of *G. concinna* (1946-a, p. 20, pl. 3, figs.11, 12; pl. 4, figs. 14, 15).

In Ecuador this form ranges from Upper Eocene to mid-Oligocene beds. It may be the same as specimens recorded from the Lower Oligocene of Mexico (Nuttall 1932, p. 29, pl. 6, figs. 13–15).

The second form is superficially similar but more compact, the spire is flattened and the embryonic chambers are obscure. The aperture is a crescentic slit embracing the inner coil ventrally, and usually carries a small lip. Most specimens are quadrate but forms occur identical in all respects except for having five, six and even seven chambers in the final coil.

In Ecuador this form ranges from mid-Oligocene at least as high as Upper Miocene and it is very abundant in the early Miocene.

GLOBOROTALIA CENTRALIS Cushman and Bermudez
Plates 26, figures 27–29

*Globorotalia centralis* CUSHMAN and BERMUDEZ, 1937, Contr. Cushman Lab. Foram. Res., vol. 13, p. 26, pl. 2, figs. 62–65.

A precise quadrate coil, dorsal face flat or slightly convex, chambers high (side-view) in relation to their width (radial). In dorsal aspect each chamber tends to overlap the next one formed, emphasizing the square coiling. The distinctive aperture is a narrow slit at the base of the final chamber extending at least over the two previous chambers and sometimes to part of the next. There is no umbilical opening.

Prior to its original description from the Eocene of Cuba this species had been rereferred to *Globigerina inflata* from the Upper Eocene Pauji of Venezuela with the comment "common in the Upper and Middle Eocene of Mexico, the Upper Eocene of Trinidad and is recorded from the Middle Eocene of Texas" (Nuttall 1935, p. 130). A form recorded as *G. inflata* from the Ponce of Porto Rico, apparently from the Lower Oligocene, may be related (Galloway and Heminway 1941, p. 412, pl. 29, fig. 3). *G. centralis* is recorded as such from the Jackson Eocene of Mississippi (Berquist 1942, p. 97, pl. 9, figs. 34, 36, 37). The figured specimens from the Upper Eocene tend to be planoconvex with a cuboidal aspect. In Trinidad and Ecuador there is an evolutionary tendency towards inflation with decreasing age, so that the Oligocene specimens show a more globular shape and should probably be referred to a separate variety. In Ecuador, and also Trinidad, the range of the species, inclusive of the inflated variety, is from Upper Eocene to mid-Oligocene. In association with *Globigerina* cf. *concinna* it is an excellent guide for distinguishing the older from the younger Oligocene.

GLOBIGERINA cf. CONCINNA Reuss 1850
Plate 25, figures 19–21

*Globigerina concinna* REUSS, 1850, Denkschr. Akad. Wiss. Wien, vol. 1, p. 373, pl. 47, fig. 8; Cushman 1946-a, p. 20, pl. 3, figs. 10–12; pl. 4, figs. 11–15.

Dorsally a spire of subglobular chambers increasing in size slowly but very regularly, chamber diameters approximately doubling

every fourth chamber. Invariably five chambers in the final coil. Ventral aspect of symmetrical pentagonal rosette of chambers around an open umbilicus. Aperture a simple circular opening directed upwards into the umbilicus and usually concealed in the direct ventral aspect.

This form has been variously described in tropical America as *G. concinna* and *G.* cf. *concinna*. Recently Cushman (loc. cit.) re-figured topotypes of *G. concinna* Reuss and placed *G. diplostoma* in its synonymy. Although very similar to the European type, the American species differs in its very regular form, invariably with five chambers in the final coil and a low rate of increase in chamber size. It is probably a distinct species and because of its limited stratigraphic range deserves careful separation from the "*G. bulloides*" tribe. The specimen figured from the Pliocene Charco Azul of Panama, for instance, is rather of the *bulloides* group (Coryell and Mossman 1942, p. 238, pl. 36, fig. 27).

In Ecuador *G.* cf. *concinna* appears sparingly in the Upper Eocene and increases steadily in abundance into the lower Middle Oligocene, at which level it dies out abruptly. It has also been recorded from the Lower Oligocene Alazan of Mexico (Nuttall 1932, p. 29, pl. 6, figs. 9–11), the Lower Oligocene Cipero of Trinidad (Cushman and Stainforth 1945, p. 67, pl. 13, fig. 1) and the "Lower Oligocene" Carapita of Venezeula (Franklin 1944, p. 317, pl. 48, fig. 5; see comments later in this paper, p. 145). Unrecorded occurrences are known to the writer in the late Eocene of Cuba and Peru, the Eo-Oligocene San Fernando of Trinidad and the Lower Oligocene Codrington College marl of Barbados (in samples examined through the courtesy of A. Senn).

### GLOBIGERINA DISSIMILIS Cushman and Bermudez
Plate 25, figures 29–31

*Globigerina dissimilis* CUSHMAN and BERMUDEZ, 1937, Cushman Lab. Foram. Res., Contr., vol. 13, p. 25, pl. 3, figs. 4–6.

A flattened globose form with four reniform chambers in the final whorl. The most distinctive feature is a supplementary chamber bridging the umbilicus. In many specimens, presumably microspheric, the embryonic portion is a minute *Anomalina*-like group of chamberlets, totally unlike the adult form.

Prior to its original description from the Eocene of Cuba this species appears to have been identified as *G. apertura* from the Lower Oligocene Alazan of Mexico (Nuttall 1932, p. 29, pl. 8, figs. 1–3). It has also been recorded from the Upper Eocene Hospital Hill and Lower to Middle Oligocene Cipero of Trinidad (Cushman and Stainforth 1945, pp. 8, 68, pl. 13, fig. 2). P. J. Bermudez (private communication) states that it occurs in the Lower Oligocene of Cuba and the Middle Oligocene of the Dominican Republic. In Ecuador *G. dissimilis* first appears in the late Eocene and dies out in the late Middle Oligocene. As in Trinidad it ranges slightly higher than *G.* cf. *concinna* and its range in Colombia is the same, according to information supplied by C. D. Redmond.

### GLOBIGERINA VENEZUELANA Hedberg
Plate 25, figures 26–28

*Globigerina venezuelana* HEDBERG, 1937, Jour. Paleontology, vol. 11, p. 681, pl. 92, fig. 7.

A globose species, large for the genus, superficially like *Globorotalia centralis* with chambers high (side view) in relation to their width (radial). Dorsal spire slightly convex, usually with four chambers in the last whorl, meeting symmetrically and not overlapping as in *G. centralis*. In ventral aspect a large deep umbilicus is seen, ringed by the ventral extremities of the adult chambers, which are often coarsely granulose. Frequently the final chamber is abnormally small and in some specimens supplementary chamberlets are present between the principal chambers.

The type occurrence is in the Upper Oligocene Carapita of Venezuela. It is also recorded from the Upper Oligocene Cojimar of Cuba (D. K. Palmer 1941, p. 286) and the Lower to Upper Oligocene Cipero of Trinidad (Cushman and Stainforth 1945, p. 67, pl. 12, fig. 13), where it also ranges up into the Miocene. As indicated by Hedberg in his original description, this is probably conspecific with the *Globigerina* sp. (?) recorded from the Buff Bay Miocene of Jamaica (Cushman and Jarvis 1930, p. 366, pl. 34, fig. 5). C. D. Redmond (private com-

munication) reports it from the Middle Oligocene (scarce) and Upper Oligocene of Colombia. In Ecuador *G. venezuelana* occurs sparingly in the early Oligocene but becomes the dominant pelagic species in the late Middle and Upper Oligocene, persisting up to mid-Miocene.

A smaller, compressed, cuboidal form from the younger Oligocene and Miocene of Ecuador is considered to be a variety of *G. venezuelana*. although similar specimens have been recorded from the Upper Oligocene Cipero of Trinidad as *G. inflata* (Cushman and Stainforth, 1945, p. 67, pl. 12, fig. 12).

### GLOBIGERINATELLA INSUETA
Cushman and Stainforth
Plate 26, figures 16, 17

*Globigerinatella insueta* CUSHMAN and STAINFORTH, 1945, Cushman Lab. Foram. Res., Spec Publ. 14, pp. 68, 69, pl. 13, figs. 7–9.

A very distinctive form, spherical with elongate supplementary chambers covering the sutures, and multiple apertures in the form of tiny lunate openings along the margins of these chambers.

This species has been recorded only from the Cipero of Trinidad, where its short life-range marks approximately the boundary between the Middle and Upper Oligocene. In Barbados it occurs in samples of the same age, examined through the courtesy of A. Senn. In Ecuador it is rarely encountered, although plentiful in the few samples which have yielded it, and all records are from the late Middle and early Upper Oligocene. These records suggest that *Globigerinatella insueta* should occur at comparable levels in the Venezuela-Colombia region.

### GLOBOROTALIA BARISSANENSIS Leroy
Plate 26, figures 24–26

*Globorotalia barissanensis* LEROY, 1939, Nat. Tijdschr. Nederl. indie., vol. 39, p. 265, pl. 1, figs. 8–10.

A small species more convex ventrally than dorsally. Usually seven faintly inflated chambers in the last coil. Periphery subacute. Aperture a slit on the ventral side at the base of the final chamber.

The only published American record of this species seems to be from the younger Oligocene Cipero formation of Trinidad (Cushman and Stainforth 1945, p. 70, pl. 13, fig. 15), but C. D. Redmond has noted

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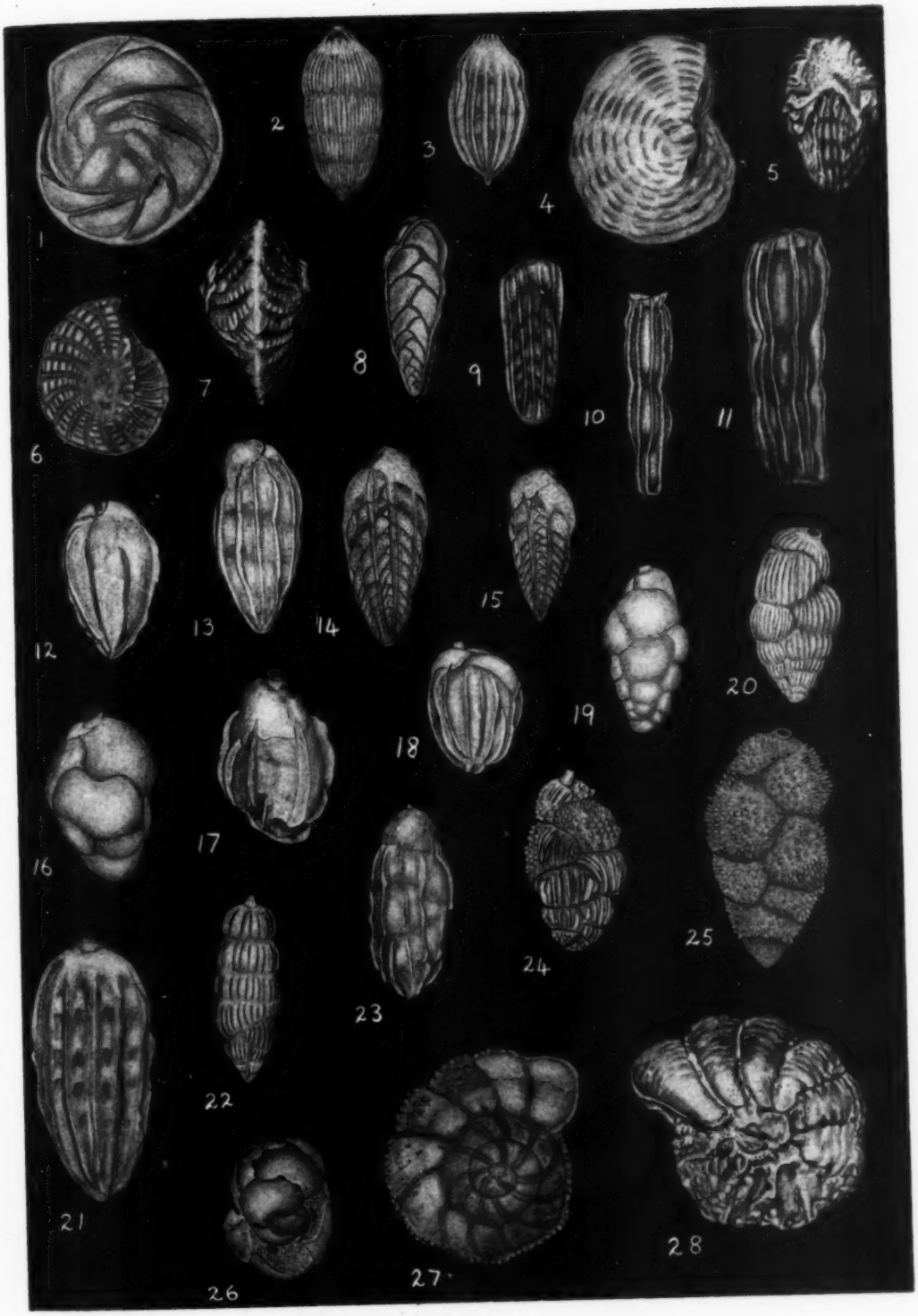
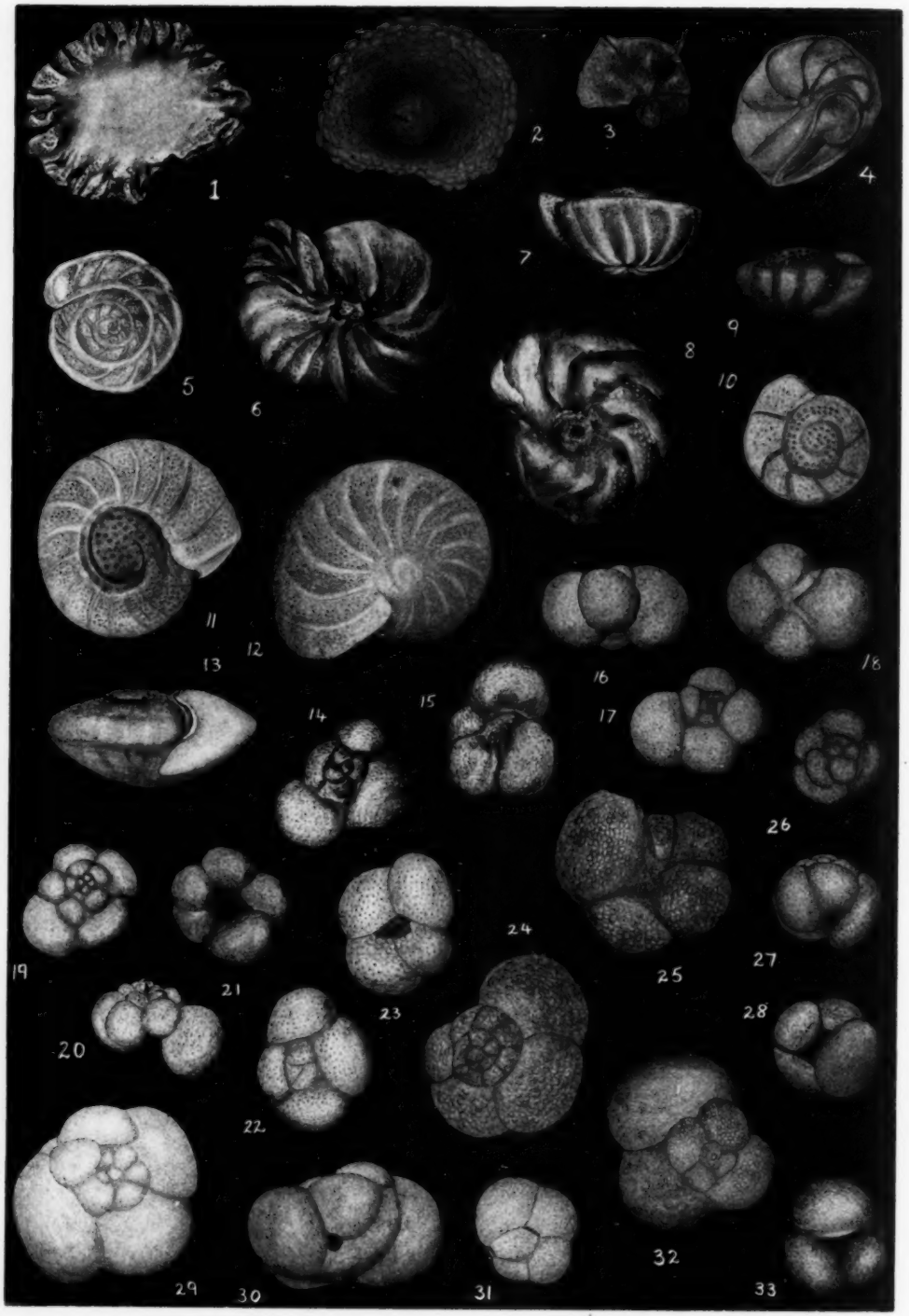
### EXPLANATION OF PLATE 24

FIGS. *1*—*Robulus clericii* (Fornasini). (×36). Upper Oligocene. (p. 131)
*2, 3*—*Pseudoglandulina comatula* (Cushman). *2*, fine-ribbed form; *3*, coarse-ribbed form often referred to as *P. gallowayi*. (×24). Upper Oligocene. (p. 131)
*4, 5*—*Elphidium* sp. A. *4*, side aspect (×75); *5*, peripheral aspect (×55). Middle Miocene. (p. 133)
*6, 7*—*Elphidium* sp. B. *6*, side aspect (×36); *7*, peripheral aspect (×45). Middle Miocene. (p. 133)
*8*—*Bolivinita* cf. *quadrilatera* (Schwager). (×36). Upper Miocene. (p. 133)
*9–11*—*Amphimorphina* sp. *9*, initial portion (×75); *10*, adult portion, edge-view showing inflation of later chambers (×55); *11*, adult portion, front aspect (×75). Upper Eocene. (p. 129)
*12*—*Bulimina jacksonensis* Cushman. (×36). Upper Eocene. (p. 127)
*13*—*Bulimina sculptilis* Cushman. (×36). Lower Oligocene. (p. 128)
*14, 15*—*Bolivina costata* d'Orbigny vars. (×36). Lower Miocene. (p. 132)
*16*—*Uvigerina carapitana* Hedberg. (×36). Upper Oligocene. (p. 132)
*17*—*Uvigerina curta* Cushman and Jarvis. (×36). Lower Oligocene. (p. 129)
*18*—*Uvigerina mexicana* Nuttall. (×36). Lower Oligocene. (p. 129)
*19*—*Uvigerinella californica* Cushman. (×36). Lower Miocene. (p. 132)
*20*—*Uvigerinella obesa* Cushman. (×36). Lower Miocene. (p. 133)
*21*—*Siphogenerina transversa* Cushman. (×24). Upper Oligocene. (p. 131)
*22*—*Siphogenerina multicostata* Cushman and Jarvis. (×36). Upper Oligocene. (p. 132)
*23*—*Uvigerina topilensis* Cushman. (×36). Lower Oligocene. (p. 130)
*24*—*Uvigerina peregrina parvula* Cushman. (×36). Upper Miocene. (p. 133)
*25*—*Uvigerina rustica* Cushman and Edwards. (×36). Upper Oligocene. (p. 130)
*26*—*Stichocassidulina thalmanni* Stone. (×24). Partly crushed, as is usual with large specimens. Upper Eocene. (p. 127)
*27, 28*—*Rotalia mexicana mecatepecensis* Nuttall. *27*, dorsal aspect; *28*, ventral aspect. (×36). Lower Oligocene. (p. 130)




Stainforth, Tertiary Foraminifera




Stainforth, Tertiary Foraminifera

it in the Upper Oligocene of Colombia (private communication) and the writer has identified the same form in samples from the Upper Cojimar of Cuba supplied by P. J. Bermudez. In Ecuador it is a valuable marker for the late Middle and the Upper Oligocene. Occasional large specimens are reminiscent of the more familiar *G. fohsi*, but radial lengthening of the later chambers, characteristic of the latter species, is not conspicuous in any of the Ecuadorean specimens.

GLOBIGERINOIDES CONGLOBATA (Brady)
Plate 26, figure 4

*Globigerina conglobata* BRADY, 1879, Quart. Jour. Micr. Sci., vol. 19, p. 286.

Typical of the genus in having prominent supplementary apertures on the dorsal side, but distinctive in its globular form. Sutures only slightly depressed. The last chamber is globose and larger than all the earlier part of the test.

This species was recorded from the late Middle and Upper Oligocene Cipero of Trinidad (Cushman and Stainforth 1945, p. 68, pl. 13, fig. 6) and it occurs at the same levels in Ecuador. C. D. Redmond states that it is not known below the Upper Oligocene in Colombia (private communication).

GLOBOROTALIA PRAEMENARDII
Cushman and Stainforth
Plate 26, figures 34, 35

*Globorotalia praemenardii* CUSHMAN and STAINFORTH, 1945, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 70, pl. 13, fig. 14.

This species is considered ancestral to *G. menardii*, from which it differs only in a more delicate construction and especially in the absence of a thick ropy keel. The types were described from the younger Oligocene Cipero of Trinidad, where it ranges into the Lower Miocene Lengua (loc. cit., p. 9). It appears in the Upper Oligocene of Colombia, according to a personal communication from C. D. Redmond. A similar form is present in samples from the Upper Oligocene Cojimar of Cuba sent to the writer by P. J. Bermudez. In Ecuador it has the same range, consistently appearing some distance below the first appearance of the heavy-keeled *G. menardii*.

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EXPLANATION OF PLATE 25.

FIGS. *1, 2—Halkyardia* sp. *1*, ventral aspect; *2*, dorsal aspect by reflected and transmitted light (×24). Lower Oligocene. (p. 130)

*3—Hantkenina alabamensis* Cushman. (×36). Upper Eocene. (p. 127)

*4—Palmerinella thalmanni* Stainforth and Stevenson. Oblique ventral view (×75). Lower Miocene. (p. 133)

*5–7—Cibicides mexicanus* Nuttall. *5*, dorsal aspect (×24); *6*, ventral aspect (×36); *7*, peripheral aspect (×28). Lower Oligocene. (p. 130)

*8–10—Cibicides perlucidus* Nuttall. *8*, ventral aspect (×36); *9*, peripheral aspect (×24); *10*, dorsal aspect (×24). Lower Oligocene. (p. 129)

*11–13—Cibicides trinitatensis* Nuttall. *11*, dorsal aspect; *12*, ventral aspect; *13*, peripheral aspect (×36). Upper Oligocene. (p. 131)

*14, 15—Globigerina* aff. *bulloides* d'Orbigny form A. *14*, dorsal aspect; *15*, ventral aspect (×48). Lower Oligocene. (p. 118)

*16–18—Globigerina* aff. *bulloides* d'Orbigny form B. *16*, peripheral aspect; *17*, dorsal aspect; *18*, ventral aspect (×75). Lower Miocene. (p. 118)

*19–21—Globigerina* cf. *concinna* Reuss. *19*, dorsal aspect; *20*, peripheral aspect; *21*, ventral aspect (×75). Lower Oligocene. (p. 118)

*22, 23—Globigerina digitata* Brady. *22*, dorsal aspect; *23*, ventral aspect (×36). Upper Oligocene. (p. 123)

*24, 25—Globigerina danvillensis* Howe and Wallace. *24*, dorsal aspect; *25*, ventral aspect (×75). Upper Eocene. (p. 117)

*26–28—Globigerina venezuelana* Hedberg. *26*, dorsal aspect; *27*, peripheral aspect; *28*, ventral aspect (×36). Upper Oligocene. (p. 119)

*29–31—Globigerina dissimilis* Cushman and Bermudez. *29*, dorsal aspect (×75); *30*, peripheral aspect (×75); *31*, ventral aspect (×36). Lower Oligocene. (p. 119)

*32, 33—Globigerina triloculinoides* (?) Beck (not Plummer). *32*, dorsal aspect (×75); *33*, ventral aspect (×36). Upper Eocene. (p. 117)

GLOBIGERINELLA AEQUILATERALIS (Brady)
Plate 26, figure 10

*Globigerina aequilateralis* BRADY, 1879, Quart. Jour. Micr. Sci., vol. 19, p. 285.

Distinctive in its nautiloid coiling, with five inflated chambers per whorl and a crescentic aperture at the base of the final chamber, symmetrically embracing the inner coil.

This species has been recorded in the fossil state from the Miocene Bowden of Jamaica (D. K. Palmer 1945, p. 69) and the Oligocene Carapita of Venezuela (Franklin 1944, p. 318, pl. 48, fig. 6; ? Hedberg 1937, p. 681). It is known to the writer from the Miocene of Trinidad. In Colombia immature specimens are locally common in the Upper Oligocene but adults are rare (private communication from C. M. B. Caudri and D. C. Redmond). In Ecuador it appears sparingly in the late Oligocene and is often abundant in the earlier Miocene.

GLOBIGERINOIDES TRILOBA (Reuss)
Plate 26, figures 5, 6

*Globigerina triloba* REUSS, 1850, Denkschr. Akad. Wiss. Wien., vol. 1, p. 374, pl. 47, fig. 11; J. A. CUSHMAN, 1946, Cushman Lab. Foram. Res. Contr., vol. 22, pt. 1, p. 20, pl. 4, figs. 16–18.

This form differs from *G. sacculifera* (see below) in the absence of bizarre final chambers, even in the largest specimens. It seems probable that *G. sacculifera* is an evolutionary offshoot from the ancestral *G. triloba*.

This species is recorded from the Miocene Port-au-Prince beds of Haiti (Coryell and Rivero, 1940, p. 340), and the Pliocene Charco Azul of Panama (Coryell and Mossman 1942, p. 238, pl. 36, fig. 29, 30). The same species was recorded as *G. sacculifera*, evidently either the young stages of this species or a primitive variety which has not developed the very long adult chambers, from the younger Oligocene Cipero of Trinidad (Cushman and Stainforth 1945, p. 68, pl. 13, fig. 3). It ranges well into the Miocene of Trinidad. In Ecuador it first appears in the late Middle Oligocene and is present in abundance throughout the Upper Oligocene and Miocene.

GLOBIGERINOIDES SACCULIFERA (Brady)
Plate 26, figures 7–9

*Globigerina sacculifera* BRADY, 1877, Geol. Mag., Dec. 2, vol. 4, p. 535. BRADY, 1884, Rept. Voyage Challenger, Zool., vol. 9, p. 604, pl. 80, figs. 11–17, pl. 82, fig. 4.

A squat trochoid species with large lunate apertures on both dorsal and ventral sides. Successive chambers roughly equal in size to all the preceding test. Chamber form at first regular, subglobular, but with maturity taking on bizarre bean- and kidney-shaped forms.

Specimens with these distinctive adult chambers have been described in the fossil state from the Miocene Choctawhatchee marl of Florida (Cushman 1918, p. 57), the Miocene Port-au-Prince beds of Haiti (Coryell and Rivero 1940, p. 340, pl. 42, figs. 24, 25, 32), the Miocene Bowden and Buff Bay beds of Jamaica (D. K. Palmer, 1945, p. 68; Cushman and Jarvis 1930, p. 366, pl. 34, fig. 4) and the Pliocene Charco Azul of Panama (Coryell and Mossman 1942 p. 238, pl. 36, fig. 28). This species also occurs in the Lower Miocene Lenuga of Trinidad as well as the Upper Oligocene of Colombia (C. D. Redmond, private communication). In Ecuador it is very scarce in the late Oligocene but becomes commoner through the early Miocene until at certain levels in the Middle and Upper Miocene it is present in flood abundance.

GLOBIGERINOIDES RUBRA (d'Orbigny)
Plate 26, figures 11, 12

*Globigerina rubra* D'ORBIGNY, 1839, in Ramon de la Sagra, Histoire naturelle et physique de l'Ile de Cuba.

This species is distinguished from the *triloba-sacculifera* suite by its lofty spire of almost globular chambers, four to each coil. Except in the juvenile stages the supplementary apertures on the dorsal face are large and prominent.

In the fossil state *G. rubra* has been recorded from the Miocene Bowden of Jamaica (D. K. Palmer 1945, p. 68), the Miocene Port-au-Prince beds of Haiti (Coryell and Rivero, 1940, p. 340), the Upper Oligocene Cipero and Lower Miocene Lengua of Trinidad (Cushman and Stain-

forth, 1945, pp. 9, 68). C. D. Redmond has stated in a private communication that in Colombia it is rare, ranging upwards from fairly high in the Upper Oligocene. In Ecuador it is not a common species but has been recorded throughout the Upper Oligocene and Miocene.

GLOBOROTALIA CANARIENSIS (d'Orbigny)
Plate 26, figures 30–32

*Rotalia canariensis* D'ORBIGNY, 1839, in Barker, Webb, and Berthelot, Hist. Nat. Iles Canaries, vol. 2, pt. 2, p. 130, pl. 1, figs. 34, 35.

A species with obliquely overlapping chambers on the dorsal side, creating a lobulate outline, but almost straight radial sutures on the ventral side. Four to five chambers in the last coil. Periphery sharply defined but rounded, aperture small, ventral, at the base of the final chamber.

In the fossil state *G. canariensis* has been widely recorded from late Tertiary strata, for example the Aguide Oligocene of Venezuela (Cushman 1929, p. 101, pl. 14, fig. 14), the Miocene Port-au-Prince beds of Haiti (Coryell and Rivero 1940, p. 336, pl. 43, fig. 27), the Upper Oligocene of Ecuador (Galloway and Morrey 1929, p. 25), the Papantla Oligocene of Mexico (Dorr 1933, p. 435) and the Upper Oligocene Cipero of Trinidad (Cushman and Stainforth 1945, p. 70, pl. 13, fig. 12). The small form of the species persists into the Miocene of Trinidad. C. D. Redmond has noted this species in the Upper Oligocene of Colombia (private communication.) In Ecuador it ranges unobtrusively throughout the Upper Oligocene and the Miocene.

GLOBIGERINA DIGITATA Brady
Plate 25, figures 22, 23

*Globigerina digitata* BRADY, 1879, Quart. Jour. Micr. Sci., vol. 19, p. 286.

A species characterized by prolongation of the later chambers into thumb-like shapes. The early chambers are compact and not readily discernible. There is no well defined aperture, only gaping sutures on the ventral side. The shell is unusually thick and coarsely cancellate for the genus.

In Trinidad this species was recorded from the Upper Oligocene (Nuttall 1928, p. 96; Cushman and Stainforth 1945, p. 68, pl. 13, fig. 5). It is present in samples of the Upper Oligocene Cojimar of Cuba submitted to the writer by P. J. Bermudez. In Ecuador it is rare, confined to the Upper Oligocene.

CANDORBULINA UNIVERSA Jedlitschka
Plate 26, figure 33

*Candorbulina universa* JEDLITSCHKA, 1933, Verh. Nat. Ver. Brünn, 65J, 1934 (1933), p. 21, figs. 1–7, 19, 21–23.

A spherical form with trochoid nuclear portion usually visible. No main aperture present, but a ring of apertural pores near the margin of the final chamber.

Probably many of the records of *Orbulina universa* should be reidentified as this species. Definite records in America are from the Miocene of the eastern Coastal Plain of the United States, Panama and Venezuela (Cushman and Dorsey 1940, p. 42), and the Upper Oligocene and Miocene of Trinidad (Renz 1942, pp. 548, 556, 560; Cushman and Stainforth 1945, p. 69, pl. 13, fig. 10). In Ecuador the species ranges from late Oligocene through the Miocene and its range is the same in Colombia, according to a private communication from C. D. Redmond. Bilobed specimens are sometimes common, as figured by Cushman and Dorsey (1940, pl. 8, fig. 8).

GLOBIGERINOIDES sp. indet.
Plate 26, figures 13–15

This is a small species, readily distinguishable, but not completely identical with any figured species. The general form is a compressed quadrate trochoid, about as broad (radially) as high (side-view). Chambers well inflated, increasing rapidly in size. The most prominent feature is the large main aperture, a gaping circular orifice on the ventral side of the last chamber. Supplementary apertures on the dorsal side are broad slits along the spiral suture, usually obscure except in adult specimens, rather than the lunate openings of most other species. There is a general resemblance to *Globigerina apertura* as figured by Cushman from the Miocene Yorktown of Virginia (1918, p. 57, pl. 12, fig. 8) but there is no indication of supplementary apertures in the original description of that species. There is also a resemblance to *Globigerina adriatica* as described by Fornasini from

Recent material (1899, p. 582, pl. 3, figs. 6, 7, *fide* Ellis and Messina): *G. adriatica* is clearly a *Globigerinoides* and in dorsal aspect appears much like the Ecuadorean species, but the main aperture is by no means as conspicuous. D. K. Palmer (1945, p. 67, 68) has described as *Globigerina bulloides* a species from the Miocene Bowden of Jamaica "compactly coiled with 3 to 4 chambers in the final whorl; sutures deep; aperture conspicuous and subcircular . . . though they may be the young of *G. rubra* d'Orbigny no trace of multiple apertures has been noticed." This description closely matches young specimens of the Ecuadorean species which differs from *G. rubra* in the shape of the supplementary apertures, the more rapid increase in chamber size and the more obtuse spire. It is a useful guide to Miocene age in Ecuador and is especially abundant in the Middle and Upper Miocene.

SPHAEROIDINELLA DEHISCENS
(Parker and Jones)
Plate 26, figure 20

*Sphaeroidina dehiscens* PARKER and JONES, 1865, Phil. Trans., vol. 155, p. 369, pl. 19, fig. 5.

A species with an ellipsoidal form, chambers and sutures conforming to its smooth contours. Only the last three chambers are clearly visible. Aperture a prominent "letter-box" slit along the ventral margin of the final chamber. Shell rather thick, surface usually hyaline. There is some resemblance to *Globigerina digitata*, possibly an evolutionary relationship, but *S. dehiscens* is distinguished by its well-defined aperture and the absence of any elongate chambers.

This species seems to be a guide to Miocene age on a regional scale, as shown by the following records in tropical America: the Buff Bay (Manchioneal) and Bowden of Jamaica (Cushman and Jarvis 1930, p. 367, pl. 34, figs. 6, 7; D. K. Palmer 1945, p. 69); the Port-au-Prince beds of Haiti (Coryell and Rivero 1940, p. 340), the topmost Cojimar of Cuba (D. K. Palmer 1940–41; see note on p. 146). In Trinidad it appears in and above the Lengua. In Colombia C. D. Redmond records *Sphaeroidinella* sp. as abundant in some Lower Miocene beds and scarce in the Upper Oligocene, but he does not regard it as typical *S. dehiscens* (private communication). In Ecuador it occurs throughout the Miocene, but has not been recorded from Oligocene samples.

GLOBOROTALIA MENARDII (d'Orbigny)
Plate 26, figures 36, 37

*Rotalia menardii* D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 273, no. 26, modele no. 10.

A bi-convex rotaliform species, somewhat compressed, usually with five but sometimes six chambers in the final whorl. Main character a very heavy ropy keel or rim of opaque shell material around the periphery.

There seem to be no authentic records of the typical heavy-keeled form of this species in the pre-Miocene of tropical America, though the ancestral lightly-keeled *G. praemenardii* appeared in the late Oligocene. Nuttall recorded and figured typical *G. menardii* from the Lower Oligocene Alazan of Mexico (1932, p. 29, pl. 4, fig. 16), but he also included other species which hint at the accidental inclusion of some younger material in his collections (see comments below, p. 145). Miocene records include the Bowden of Jamaica (D. K. Palmer 1945, p. 70), the Port-au-Prince beds of Haiti (Coryell and Rivero 1940, p. 336, pl. 42, figs. 34, 35), the Miocene of St. Croix, V. I. (Cushman 1946-b, p. 13), the Quebradillas of Porto Rico (Galloway and Heminway 1941, p. 280), the Lengua and Brasso of Trinidad (Nuttall 1928, p. 101, pl. 7, fig. 20; Renz 1942, p. 556, 560; Cushman and Stainforth 1945, p. 9), the upper Agua Salada of Venezuela (Renz 1942, p. 553), the topmost Cojimar of Cuba (D. K. Palmer 1940–41, see comments below, p. 146), the Uscari of Costa Rica (K. V. W. Palmer, 1923, pp. 4, 9) and the Permenter's Farm beds of Florida (Smith 1941, p. 273). C. D. Redmond states in a private communication that the heavy-keeled form first appears in the Lower Miocene of Colombia, except for rare specimens in the Upper Oligocene which could be referred to either *G. menardii* or *G. praemenardii*. It is also recorded from the Pliocene Charco Azul of Panama (Coryell and Mossman 1942, p. 234, pl. 36, fig. 5). In Ecuador *G. menardii*, together with *Sphaeroidinella dehiscens*, appears consistently just above the level at which *Globorotalia barissanensis*, *Globigerina digitata* and *Globigerinoides conglobata* become extinct. The

time-plane so marked is treated as the Oligocene-Miocene boundary.

### GLOBOROTALIA MENARDII (d'Orbigny) vars. FIJIENSIS Cushman, and MULTICAMERATA(?) Cushman and Jarvis
Plate 26, figures 38, 39

*Globorotalia menardii* var. *fijiensis* CUSHMAN, 1934, Bernice P. Bishop Mus. Bull., no. 119. p. 36, pl. 16, fig. 5; CUSHMAN and JARVIS, Jour. Paleontology, vol. 4, p. 367, pl. 34, fig. 8.

The specimens of *G. menardii* from Lower and early Middle Miocene samples in Ecuador are five- or rarely six-chambered forms. In the late Middle and Upper Miocene this becomes outnumbered by specimens with from six to nine chambers in the final coil. Some of these are deeply umbilicate and closely similar to the variety *G. menardii fijiensis* described from the late Tertiary of Fiji and seen, by courtesy of B. Stone, in Upper Miocene samples from the Netherlands East Indies. The variety *G. menardii multicamerata* is not greatly different and it is interesting that this variety from the Buff Bay (Manchioneal) of Jamaica is not recorded from the slightly older Bowden (Middle Miocene) nor its presumed equivalent in Haiti, the Port-au-Prince beds. This multicamerate form is known to the writer from beds in southwestern Colombia at the same levels as the Ecuadorean occurrence and it has been seen in Middle Miocene samples from the Dominican Republic, in the collection of B. Stone. Possibly the appearance of multicamerate *G. menardii* is regionally valuable in recognizing the late Miocene in the few areas of tropical America where there are neritic deposits of that age.

### PULLENIATINA OBLIQUILOCULATA (Parker and Jones)
Plate 26, figures 21–23

*Pullenia sphaeroides* var. *obliquiloculata* PARKER and JONES, 1865, Royal Soc. London, Phil. Trans., vol. 155, pp. 365, 368, pl. 19, figs. 4a, b.

This species is coiled in an inflated trochoid with four or five chambers in the last whorl. The dorsal face is flattened, the ventral side moderately concave but nonumbilicate. The most characteristic feature is a tendency for successive chambers to overlap further over the dorsal face, thus approaching involute planispiral coiling. At least in the Ecuadorean specimens this final state is never reached, although the tendency towards it is clearly discernible. Other characters are the prominent lunate aperture, ventrally disposed, and the smooth polished surface of the test. In the original description similarity to *Globigerina inflata* is noted and a probable relationship is suggested by Cushman's figures of topotype specimens of the latter species (1946-a, p. 16, pl. 4, figs. 1–4).

In the fossil state *Pulleniatina obliquiloculata* is recorded from the Pliocene Charco Azul of Panama (Coryell and Mossman 1942, p. 31, pl. 36, fig. 31) as well as the late Miocene and early Pliocene of the Netherlands East Indies (LeRoy 1941, pp. 14, 18, 44, 45, 65, pt. 1, pl. 2, figs. 105–107; pt. 2, pl. 4, figs. 16–18). It is known from the Recent of the southern Pacific and B. Stone has shown the writer Recent material with typical specimens collected near Cuba. In Ecuador the species appears in moderate abundance in the neritic facies of the Upper Miocene.

## BENTHONIC SMALLER FORAMINIFERA

In Upper Cretaceous and early Tertiary times, foraminiferal assemblages were constant over wide areas. In faunas of these ages the succession of genera and species is found to be much the same in localities thousands of miles apart. This is as true of the benthonic as of the pelagic species. In the middle and late Tertiary however, a pronounced provincialism affected the faunas and, with a few exceptions among the benthonic forms, only the pelagic species are reliable as time-markers in a regional sense. Among the bulk of the benthonic genera, evolution followed localized trends confined to individual basins and embayments. Under similar facies conditions very similar foraminiferal assemblages developed at different times in different areas. Great confusion can arise by failure to recognize these facts, which underlie the erratic age-assignments published for several tropical American microfaunas. A typical case, cited not because it is unique but because the faulty argument is so clearly stated, is the correlation of the older Oligocene Alazan fauna of Mexico with the younger

Oligocene faunas of Venezuela and Ecuador (Dorr 1933, pp. 434–438). Hedberg (1937, pp. 685, 695) has commented on this case and others.

In the list which follows only those benthonic Foraminifera are included which have limited ranges in Ecuador corresponding to their recorded distribution in tropical America. On the evidence so far accumulated these species can be regarded as time-markers as distinct from the many long-ranging species which indicate little beyond facies resemblance. They are listed and discussed in approximately their order of stratigraphic appearance. Levels of extinction are given as far as possible, but in some instances apparent extinction at the end of the Oligocene epoch in Ecuador may be only a reflection of the elimination of the local neritic facies at that time. The systematic arrangement of the species discussed is as follows:

Order FORAMINIFERA
- Family LAGENIDAE
  - Subfamily NODOSARIINAE
    - Genus *Robulus*
      - Species *R. clericii* (p. 131, Pl. 24, fig. 1)
    - Genus *Pseudoglandulina*
      - Species *P. comatula* (p. 131, Pl. 24, figs. 2, 3)
- Family NONIONIDAE
  - Genus *Elphidium* (p. 133, Pl. 24, figs. 4–7)
- Family HETEROHELICIDAE
  - Subfamily BOLIVINITINAE
    - Genus *Bolivinita*
      - Species *B.* cf. *quadrilatera* (p. 133, Pl. 24, fig. 8)
  - Subfamily PLECTOFRONDICULARIINAE
    - Genus *Amphimorphina* (p. 129, Pl. 24, figs. 9–11)
- Family BULIMINIDAE
  - Subfamily BULIMININAE
    - Genus *Bulimina*
      - Species *B. jacksonensis* (p. 127, Pl. 24, fig. 12)
      - *B. sculptilis* (p. 128, Pl. 24, fig. 13)
  - Subfamily VIRGULININAE
    - Genus *Bolivina*
      - Species *B. costata* (p. 132, Pl. 24, figs. 14, 15)
  - Subfamily UVIGERININAE
    - Genus *Uvigerinella*
      - Species *U. californica* (p. 132, Pl. 24, fig. 19)
      - *U. obesa* (p. 133, Pl. 24, fig. 20)
    - Genus *Uvigerina*
      - Species *U. carapitana* (p. 132, Pl. 24, fig. 16)
      - *U. curta* (p. 129, Pl. 24, fig. 17)
      - *U. gallowayi* (p. 129)
      - *U. mexicana* (p. 129, Pl. 24, fig. 18)
      - *U. peregrina parvula* (p. 133, Pl. 24, fig. 24)
      - *U. rustica* (p. 130, Pl. 24, fig. 25)
      - *U. topilensis* (p. 130, Pl. 24, fig. 23)
    - Genus *Siphogenerina*
      - Species *S. basispinata* (p. 132)
      - *S. multicostata* (p. 132, Pl. 24, fig. 22)
      - *S. transversa* (p. 131, Pl. 24, fig. 21)

Family ROTALIIDAE
  Subfamily ROTALIINAE
    Genus *Rotalia*
      Species *R. mexicana mecatepecensis* (p. 130, Pl. 24, figs. 27, 28)
Family CYMBALOPORIDAE
    Genus *Halkyardia* (p. 130, Pl. 25, figs. 1, 2)
Family CASSIDULINIDAE
  Subfamily CASSIDULININAE
    Genus *Stichocassidulina*
      Species *S. thalmanni* (p. 127, Pl. 24, fig. 26)
Family HANTKENINIDAE
    Genus *Hantkenina* (p. 127, Pl. 25, fig. 3)
Family ANOMALINIDAE
  Subfamily ANOMALININAE
    Genus *Palmerinella* (p. 133, Pl. 25, fig. 4)
  Subfamily CIBICIDINAE
    Genus *Cibicides*
      Species *C. mexicanus* (p. 130, Pl. 25, figs. 5–7)
      *C. perlucidus* (p. 129, Pl. 25, figs. 8–10)
      *C. trinitatensis* (p. 131, Pl. 25, figs. 11–13)

### HANTKENINA spp.
Plate 25, figure 3

This genus, to judge from its morphology and the wide distribution of its species, may have been pelagic, but in the absence of direct evidence to this effect it is treated here as benthonic. Thalmann (1942-a,-b; 1946-b, pp. 1236, 1237) has published a detailed summary of records of the stratigraphic distribution of *Hantkenina*. In tropical and northern America he mentions occurrences in the Eocene of Venezuela, Trinidad, Bonaire, Barbados, Cuba, Panama, Mexico, Texas, California, Louisiana, Alabama and sub-Atlantic cores. Additional records are from the Chira of Peru (Stone 1946, pp. 60, 61) and the late Eocene of Colombia (C. D. Redmond, private communication). The one recorded appearance in the Oligocene (basal) is in Alabama, and it seems probable that these specimens were reworked.

In Ecuador species close to *Hantkenina* (*Hantkenina*) *alabamensis* have been obtained from the Upper Eocene at several widely separated localities. Hundreds of Lower Oligocene samples have been examined but there has only been one record of *Hantkenina*, in a manuscript note by B. Stone. The Lower Oligocene in the area of this sample is mildly unconformable on the Upper Eocene and it is reasonable to attribute this isolated occurrence to reworking. In the Upper Eocene of southwest Ecuador *Hantkenina* is very scarce and the specimens are small with a primitive arrangement of chambers and spines, suggestive of the Middle Eocene subgenus *Applinella*. They seem to be exactly the same, however, as the initial portions of mature *H. alabamensis* from localities to the north and they can therefore be determined as immature individuals of the Upper Eocene subgenus *Hantkenina*.

### STICHOCASSIDULINA THALMANNI Stone
Plate 24, figure 26

*Stichocassidulina thalmanni* STONE, 1946, Jour. Paleontology, vol. 20, pp. 59–61, figs. 1, 2.

Specialized short-lived forms of the Cassidulinidae frequently lend themselves to definition of narrow zonal units. This species, so far as known occurs only in correlative beds in the Upper Eocene of northern Peru, the type occurrence, and of southern and central western Ecuador. It may be adapted to a specialized facies and thus limited in lateral distribution, but it is an excellent index species and should be searched for in neighboring countries.

### BULIMINA JACKSONENSIS Cushman
Plate 24, figure 12

*Bulimina jacksonensis* CUSHMAN, 1925, Cushman Lab. Foram. Res., Contr., vol. 1, p. 6, pl. 1, figs. 6, 7.

BULIMINA SCULPTILIS Cushman
Plate 24, figure 13

*Bulimina sculptilis* CUSHMAN, 1923, U. S. Geol. Survey, P. P. 133, p. 23, pl. 3, fig. 3.

These two species are members of an evolutionary series. The older *B. jacksonensis* has a more obtuse initial angle and tapers throughout its growth, whereas the younger *B. sculptilis* has a more acute initial angle and the initial tapering portion merges into an almost cylindrical adult portion. The number of lamellate costae is variable and usually not of stratigraphic significance.

Forms referred to *B. jacksonensis* are recorded from the Upper Eocene of the Gulf states (Cushman 1946-c, p. 23), Mexico (type reference and Nuttall 1935, p. 127), Panama (Coryell and Embich 1937, p. 304, pl. 42, fig. 17), Venezuela (Nuttall 1935, p. 127, pl. 15, fig. 1; Renz 1942, p. 540), and Trinidad (Renz 1942, p. 541; Cushman and Stainforth 1945, p. 10) and a variety occurs in the Eo-Oligocene of Oregon (Detling 1946, p. 356, pl. 49, figs. 13, 15, 16). In Colombia its range, including varieties, is Upper and upper Middle Eocene (C. D. Redmond, private communication) and it occurs in the Upper Eocene of Northern Peru (B. Stone, private communication).

Records of *B. sculptilis* include the Lower Oligocene of Mississippi (type reference), and Mexico (Nuttall 1932, p. 19, pl. 5, fig. 1), the Oligocene of Venezuela (Renz 1942, p. 553), the Eo-Oligocene of California (Condit 1930, pp. 260, 262; Kleinpell 1938, p. 102, 177; Cushman and McMasters 1936, p. 513, pl. 75, fig. 3), the Lower Oligocene of Oregon (Nuttall, loc. cit.) and the Oligocene of Nicaragua (Dorr 1933, p. 346). This species also occurs in the Oligocene of Trinidad. In Colombia it appears just above the youngest definite Upper Eocene (C. D. Redmond, private communication) and it is known in the Lower Oligocene (abundant) and the

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EXPLANATION OF PLATE 26

FIGS. *1–3—Globigerina wilsoni* (?) Cole. *1*, peripheral aspect; *2*, dorsal aspect; *3*, ventral aspect (×75). Upper Eocene. (p. 117)

*4—Globigerinoides conglobata* (Brady). Dorsal aspect (×36). Upper Oligocene. (p. 121)

*5, 6—Globigerinoides triloba* (?) (Reuss). *5*, dorsal aspect; *6*, ventral aspect (×36). Lower Miocene. (p. 122)

*7–9—Globigerinoides sacculifera* (Brady). *7*, dorsal aspect; *8*, ventral aspect; *9*, peripheral aspect (×36). Middle Miocene. (p. 122)

*10—Globigerinella aequilateralis* (Brady). Oblique view (×36). Lower Miocene. (p. 122)

*11, 12—Globigerinoides rubra* (d'Orbigny). *11*, dorsal aspect; 12, side aspect (×75). Middle Miocene. (p. 122)

*13–15—Globigerinoides* sp. indet. *13*, dorsal aspect; *14, 15*, side aspects (×36). Miocene. (p. 123)

*16–17—Globigerinatella insueta* Cushman and Stainforth. (*16*, ×75; *17*, ×45). Figured specimens fall within the range of variation of topotype material. That figured by Cushman and Stainforth occurs in the material from Ecuador, but specimens were not available at the time the drawings were made. Figured specimens are from the late Middle Oligocene. (p. 120)

*18, 19—Hastigerinella eocenica* Nuttall. Detached adult chambers (×36). Upper Eocene. (p. 116)

*20—Sphaeroidinella dehiscens* (Parker and Jones). Ventral aspect (×36). Miocene. (p. 124)

*21–23—Pulleniatina obliquiloculata* (Parker and Jones). *21*, dorsal aspect (×36); *22*, peripheral aspect (×48); *23*, ventral aspect (×36). Upper Miocene. (p. 125)

*24–26—Globorotalia barissanensis* LeRoy. *24*, dorsal aspect; *25*, peripheral aspect; *26*, ventral aspect (×75). Upper Oligocene. (p. 120)

*27–29—Globorotalia centralis* Cushman and Bermudez, inflated var. *27*, dorsal aspect; *28*, peripheral aspect; *29*, ventral aspect (×36). Lower Oligocene. (p. 118)

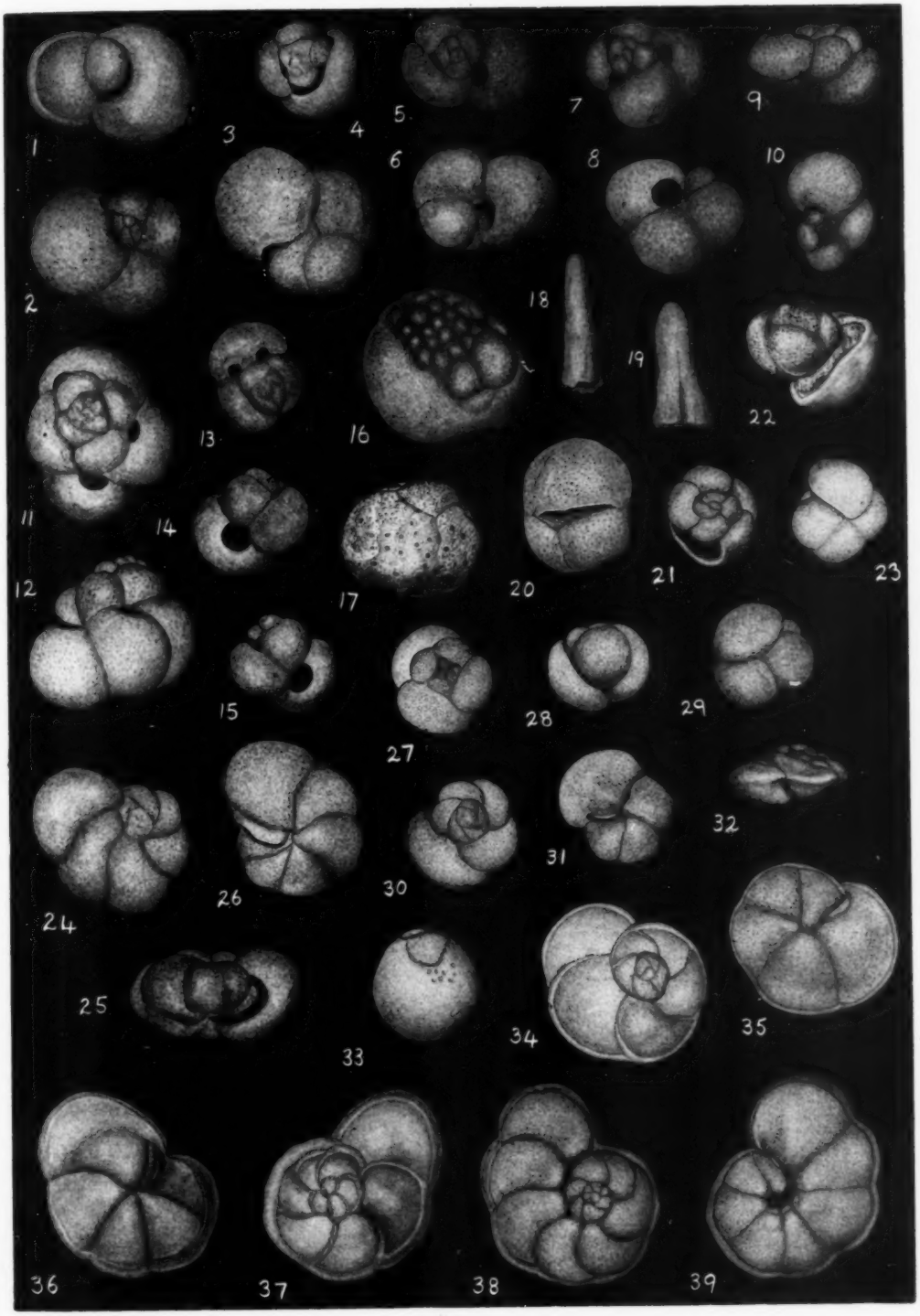
*30–32—Globorotalia canariensis* (d'Orbigny). *30*, dorsal aspect; *31*, ventral aspect; *32*, peripheral aspect (×36). Miocene. (p. 123)

*33—Candorbulina universa* Jedlitschka. (×36). Miocene, Ecuador. (p. 123)

*34, 35—Globorotalia praemenardii* Cushman and Stainforth. *34*, dorsal aspect; *35*, ventral aspect (×75). Miocene. (p. 121)

*36, 37—Globorotalia menardii* (d'Orbigny). *36*, ventral aspect; *37*, dorsal aspect ( ×36). Miocene. (p. 124)

*38, 39—Globorotalia menardii* (d'Orbigny) var. *fijiensis* Cushman. *38*, dorsal aspect; *39*, ventral aspect (×36). Upper Miocene. (p. 125)




Stainforth, Tertiary Foraminifera

Upper Oligocene of Cuba (P. J. Bermudez, private communication). B. Stone has shown the writer specimens close to *B. sculptilis* from the Upper Eocene Chira of Peru.

These records show that in broad terms *B. jacksonensis* is a marker for the Upper Eocene and *B. sculptilis* for the Oligocene. In Ecuador there is a very slight overlap in their ranges, *B. sculptilis* appearing inconspicuously in the late Eocene while *B. jacksonensis* lingers into the basal Oligocene.

### AMPHIMORPHINA spp.
Plate 24, figures 9–11

Several similar species of this genus have been described from the Upper Eocene of tropical America and the southern States, including *A. lirata* Cushman and Bermudez from Cuba (1936, p. 2, pl. 1, figs. 6–8), *A. ignota* Cushman and Siegfus from California (1939, p. 27, pl. 6, figs 10–13) and *A. yazooensis* Bergquist from Mississippi (1942, p. 64, pl. 7, fig. 26). The species figured from the Upper Eocene of Venezuela as *Plectofrondicularia mexicana* appears to be a related form (Nuttall 1935, p. 127, pl. 15, fig. 6). In Colombia similar specimens are known from the upper Middle Eocene (C. D. Redmond, private communication). In Trinidad specimens of *Amphimorphina* of the same general type occur in the Upper Eocene San Fernando formation and appear to evolve upwards into the early Oligocene forms referred to *P. mexicani*. In Ecuador the distribution is the same as in Trinidad.

### CIBICIDES PERLUCIDUS Nuttall
Plate 25, figures 8–10

*Cibicides perlucidus* NUTTALL, 1932, Jour. Paleontology, vol. 6, p. 33, pl. 8, figs. 10–12.

This species was originally reported from the lower part of the Lower Oligocene Alazan of Mexico and the Porto Rico record by Galloway and Heminway (1941, p. 251, etc.) seems to be from the same zone. The species has been recorded from Cuba and a similar form occurs in the Eocene marls of Trinidad. It has also been noted from the Middle Eocene of Oregon by Bandy (1944, p. 375, pl. 62, fig. 3). In Ecuador it is present in the late Middle and Upper Eocene and is often conspicuous in the basal Lower Oligocene, but it dies out abruptly at a horizon low in the Oligocene.

### UVIGERINA CURTA Cushman and Jarvis
Plate 24, figure 17

*Uvigerina curta* CUSHMAN and JARVIS, 1929, Cushman Lab. Foram. Res., Contr., vol. 5, pt. 1, p. 13, pl. 3, figs. 13–15.

### UVIGERINA GALLOWAYI Cushman

*Uvigerina gallowayi* CUSHMAN, 1929, Cushman Lab. Foram. Res., Contr., vol. 5, pt. 4, p. 38, pl. 13, figs. 33, 34.

There is a species-group of *Uvigerina* widespread in the Eo-Oligocene of tropical America, characterized by lamellate costae on the earlier chambers. Typical representatives have been described as *U. cubana* Palmer and Bermudez, *U. curta* Cushman and Jarvis, *U. danvillensis* Howe and Wallace, *U. gallowayi* Cushman, etc. The grounds for distinction between these allied forms have never been clearly expressed and the practice of figuring only one or two specimens fails to indicate the great range of variation within each species.

The Upper Eocene and early Oligocene forms in Ecuador tend to be relatively short and thick, with prominent flange-like costae. They compare closely in morphology, range and variation with *U. curta* from the Eo-Oligocene San Fernando of Trinidad. In the late Middle and Upper Oligocene a form appears which is equally variable but on average is more elongate, with more numerous and less flaring costae. This is referred to *U. gallowayi* Cushman, originally described from the Manta fauna as *U. alata* (Galloway and Morrey, 1929, p. 36, pl. 6, fig. 1). A private communication from C. D. Redmond reports similar distribution in Colombia. The *U. gallowayi* form has been locally recorded in the Miocene of Colombia but these specimens may have been reworked.

### UVIGERINA MEXICANA Nuttall
Plate 24, figure 18

*Uvigerina mexicana* NUTTALL, 1932, Jour. Paleontology, vol. 6, p. 22, pl. 5, figs. 12, 13.

This species has been recorded from the Carapita Oligocene of Venezuela (Franklin 1944, p. 315, pl. 46, fig. 21), the Lower Oligocene Finca Adelina of Cuba (*fide* Franklin, *loc. cit.*) and, at its type locality,

from the Lower Oligocene Alazan of Mexico. It occurs in the Lower and Middle Oligocene neritic facies of Trinidad. In Ecuador it is sometimes common in the Lower Oligocene and it occasionally ranges up into the Middle Oligocene. C. D. Redmond (private communication) states that its range in Colombia is Lower and Middle Oligocene. He mentions that its upper limit is close to that of *Globigerina dissimilis*, a fact which appears to be true regionally.

UVIGERINA TOPILENSIS Cushman
Plate 24, figure 23

*Uvigerina topilensis* CUSHMAN, 1925, Cushman Lab. Foram. Res., Contr., vol. 1, pt. 1, p. 5, pl. 1, fig. 5.

This species, characterized by its blunt elongate test and sparse continuous costae, seems to retain its distinctive form over wide areas. The types came from the Upper Eocene of Mexico and a similar form was recorded there from the Lower Oligocene as *U. tenuistriata* (Nuttall 1932, p. 21, pl. 5, fig. 8). Cushman recorded it from the Jackson Eocene of the Gulf Coast (1935, p. 41). In Ecuador this species has been noted only in Lower Oligocene samples.

CIBICIDES MEXICANUS Nuttall
Plate 25, figures 5–7

*Cibicides mexicanus* NUTTALL, 1932, Jour. Paleontology, vol. 6, p. 33, pl. 9, figs. 7–9.

The types came from the lower part of the Lower Oligocene Alazan of Mexico. Cushman and Stainforth (1945, p. 73, pl. 15, fig. 5) record it from the Lower and Upper Oligocene of Trinidad, and mention its occurrence in the Eocene and Oligocene of Cuba, the Ponce of Porto Rico and the Eocene of Oregon. It should be noted that some variation in the amount of convexity was allowed in the Trinidad determinations (*loc. cit.*) and that the plano-convex form as first figured is largely confined to the early Oligocene. In Ecuador this species is confined to the Lower and early Middle Oligocene.

HALKYARDIA sp.
Plate 25, figures 1, 2

This genus is often regarded as confined to the Eocene, although Galloway has referred to its occurrence in the Oligocene of Mexico (1933, p. 320). In Trinidad it is confined to the basal Oligocene in reefal facies, and it shows the same distribution in Ecuador. The Eocene records are from France, Dalmatia and New Zealand and it is possible that in the tropical American region it would be more correct to regard *Halkyardia* as an early Oligocene marker.

ROTALIA MEXICANA MECATEPECENSIS Nuttall
Plate 24, figures 27, 28

*Rotalia mexicana mecatepecensis* NUTTALL, 1932, Jour. Paleontology, vol. 6, p. 26, pl. 4, figs. 11, 12.

Rugosity of the dorsal face distinguishes this variety from the original *R. mexicana*. In reefal facies of the Lower Oligocene of Ecuador there are abundant specimens apparently identical with Nuttall's types from the Lower Oligocene Alazan of Mexico. It occurs also in neritic shales, but is scarcer and usually smaller than in the reef deposits. Thalmann has mentioned similar and correlative assemblages in western Colombia (private report) and it is recorded as locally abundant in the Oligocene Ponce of Porto Rico (Galloway and Heminway 1941).

UVIGERINA RUSTICA Cushman and Edwards
Plate 24, figure 25

*Uvigerina rustica* CUSHMAN and EDWARDS, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, pt. 4, p. 83, pl. 14, fig. 6.

This tuberculate species was based on specimens from the Aguide Oligocene fauna of Venezuela, first figured as *U. hispida* (Cushman 1929, p. 95, pl. 13, fig. 35), and it was considered identical with species earlier recorded from the Manta fauna of Ecuador and the Oligocene of Trinidad. Later authors have indicated that it occurs only in the younger Oligocene, and Miocene, as in Trinidad (Renz 1942, p. 546, 560; Cushman and Stainforth 1945, p. 47, pl. 7, fig. 13). The form described as *U. hispida* from the Lower Zemorrian to Lower Saucesian of California appears to be the same (Kleinpell 1938, p. 295, pl. 5, figs. 8, 16). H. H. Renz mentions its occurrence in the Lower Oligocene of Venezuela (private communication). Nuttall figured a similar form as *U. auberiana* from the Lower Oligocene of

Mexico (1932, p. 21, pl. 5, fig. 7; see comments below, p. 144) and this is possibly the same as that listed by Dorr from the Oligocene of Nicaragua (1933, p. 436). Other records include the Cojimar of Cuba (D. K. Palmer 1941, p. 84, pl. 15, fig. 19), the Amoura of Costa Rica (Goudkoff and Porter 1942, p. 1652, 1653), the Oligo-Miocene of St. Croix, V. I. (Cushman 1946-b, p. 9) and (?) the Papantla fauna of Mexico (Dorr 1933, p. 435). In Cuba and the Dominican Republic this species ranges from Upper Oligocene to Recent (P. J. Bermudez, private communication). In Ecuador *U. rustica* first appears in the late Middle Oligocene and ranges up to the base of the Miocene. A similar form re-appears in the late Miocene neritic facies.

### CIBICIDES TRINITATENSIS (Nuttall)
Plate 25, figures 11–13

*Truncatulina trinitatensis* NUTTALL, 1928, Quart. Jour. Geol. Society London, vol. 84, p. 97, pl. 7, figs. 3, 5, 6.

The types came from Trinidad, where the species occurs in beds of late Middle and Upper Oligocene age. Cushman (1946-c, p. 40) mentions records from Upper Eocene to Miocene in other parts of the Caribbean region. In Ecuador it is plentiful in the late Middle and Upper Oligocene neritic facies, but is not known from higher or lower levels.

### PSEUDOGLANDULINA COMATULA Cushman
Plate 24, figures 2, 3

*Nodosaria comatula* CUSHMAN, 1923, U. S. Nat. Mus. Bull. 104, p. 82, pl. 14, fig. 5.

Hedberg recommended the use of this name for all the costate *Pseudoglandulinas* of the younger Oligocene, including the sparse-ribbed specimens often separated as *P. gallowayi*. Forms which fall under this definition have been recorded from the younger Oligocene of Venezuela (Hedberg 1937, p. 673, pl. 91, figs. 9, 10; Renz 1942, p. 544; Cushman 1929, p. 87, pl. 13, fig. 13), Trinidad (Nuttall 1928, p. 84, pl. 4, fig. 23; pl. 5, fig. 3; Renz 1942, p. 546, 556; Cushman and Stainforth 1945, p. 27, pl. 4, fig. 3), Ecuador (Galloway and Morrey 1929, p. 13, pl. 1, fig. 7), Nicaragua (Dorr 1933, p. 436), California (Kleinpell 1938, p. 221), Cuba (Palmer and Bermudez 1936), Porto Rico (Galloway and Heminway 1941, p. 338, pl. 11, fig. 2) and St. Croix, V. I. (Cushman 1946-b, p. 5). C. D. Redmond describes its occurrence in Colombia as scanty but confined to the lower part of the Upper Oligocene (private communication). There are no records from the Miocene, and the only Lower Oligocene record is open to question (Nuttall 1932, p. 16; see comments below, p. 144). In Ecuador *P. comatula* ranges from late Middle into early Upper Oligocene.

### ROBULUS CLERICII (Fornasini)
Plate 24, figure 1

*Cristellaria clericii* FORNASINI, 1895, Bologna.

This distinctive species has been recorded in the younger Oligocene and Miocene of Trinidad (Nuttall 1928, p. 87, pl. 5, fig. 10; Renz 1942, p. 557; Cushman and Stainforth 1945, p. 21, pl. 2, fig. 23), the younger Oligocene of Venezuela (Cushman 1929, p. 84, pl. 12, fig. 16, 17; Hedberg 1937, p. 669; Renz 1942, p. 554), the Oligocene of Nicaragua (Dorr 1933, p. 435, 436), the lower Zemorrian of California (Kleinpell 1938, p. 197), the Miocene of Haiti (Coryell and Rivero 1940, p. 332, pl. 43, fig. 7), the Miocene of Jamaica (D. K. Palmer 1945, p. 34), the Upper Oligocene of Cuba and the Miocene of the Dominican Republic (P. J. Bermudez, private communication). In Ecuador the species becomes conspicuous in and ranges upwards from the late Middle Oligocene, but occasional specimens with the characteristic comma-shaped chambers are known in the late Middle and Upper Eocene. The same seems to be true of its distribution in Colombia, according to C. D. Redmond, private communication.

### SIPHOGENERINA TRANSVERSA Cushman
Plate 24, figure 21

*Siphogenerina raphanus* (Parker and Jones) *transversus* CUSHMAN, 1918, U. S. Nat. Mus. Bull. 103, p. 64.

The types came from the Oligocene Culebra of Panama and the species is widely distributed in the late Oligocene and early Miocene of tropical America. Hedberg (1937, p. 677, pl. 91, fig. 18) recorded it from the Carapita of Venezuela and mentioned other occurrences in the Papantla fauna of Mexico, the Zemorrian of California, the Miocene of Colombia, the Tertiary of

Trinidad and the Oligocene of Cuba. These records have been amplified in subsequent papers but no occurrences are known older than late Middle Oligocene, except for *S. transversa* var. *cubensis* from the Eocene of Cuba (Cushman and Bermudez 1937, p. 16, pl. 2, figs. 8, 9). In Ecuador *S. transversa* ranges from late Middle Oligocene into the Miocene, and it has the same range in Colombia (C. D. Redmond, private communication). Its distribution is subject to facies control and it occurs in greatest abundance at the boundary of neritic and sub-littoral facies.

### SIPHOGENERINA BASISPINATA Cushman and Jarvis

*Siphogenerina basispinata* CUSHMAN and JARVIS, 1929, Cushman Lab. Foram. Res., Contr , vol. 5, pt. 1, p. 13, pl. 3, figs. 4, 5.

This species was first described from the "Sagrina Beds" of Trinidad, currently considered Upper Oligocene. It has also been recorded from the upper Middle and Upper Oligocene Cipero of Trinidad (Cushman and Stainforth 1945, p. 49, pl. 8, fig. 3). It has been reported from the late Oligocene of St. Croix, V. I. (Cushman 1946-b, p. 10) and occurs in the lower Upper Oligocene of Colombia (C. D. Redmond, private communication). In Ecuador it is also restricted to the younger Oligocene.

### SIPHOGENERINA MULTICOSTATA Cushman and Jarvis Plate 24, figure 22

*Siphogenerina multicostata* CUSHMAN and JARVIS, 1929, Cushman Lab. Foram. Res., Contr., vol. 5, pt. 1, p. 14, pl. 3, fig. 6.

First recorded from the "Green Clay" of Trinidad, the range of this species was later given as upper Middle and Upper Oligocene at the same locality (Cushman and Stainforth 1945, p. 49, pl. 8, fig. 1), with reported occurrences in Venezuela, Cuba and Porto Rico. It has also been recorded from the Lower Miocene of Trinidad (Renz 1942, p. 560) the Zemorrian of California (Kleinpell 1938, p. 302, pl. 5, fig. 7), the Papantla Oligocene of Mexico (Dorr 1933, p. 435, and the late Oligocene of St. Croix, V. I. (Cushman 1946-b, p. 10). In Ecuador it occurs only in the late Upper Oligocene.

### UVIGERINA CARAPITANA Hedberg Plate 24, figure 16

*Uvigerina carapitana* HEDBERG, 1937, Jour. Paleontology, vol. 11, p. 677, pl. 91, fig. 20.

As defined by Hedberg, this species from the younger Oligocene of Venezuela was considered identical with forms from the young Oligocene of Panama, Trinidad and California. In Colombia the range seems to be through late Middle and Upper Oligocene (C. D. Redmond, private communication). In Ecuador the species has a short life-range in the topmost Oligocene and is usually abundant in beds of that age near the inner margin of the neritic facies.

### BOLIVINA COSTATA d'Orbigny, and varieties Plate 24, figures 14, 15

*Bolivina costata* D'ORBIGNY, 1839, Voyage dans l'Amerique Méridionale; Foraminiferes. Strasbourg.

Specimens of *Bolivina* of this species-group are described from the Pliocene of California (Cushman 1926, pp. 41, 42, pl. 6, figs. 2, 3) but Kleinpell gives them scant attention in his discussion of the younger Tertiary of California. He refers only to *B.* cf. *interjuncta* from the Miocene (1938, p. 274). The variety *B. costata dissimilis* was described from the subsurface Miocene of Louisiana (Cushman and Ellisor 1939, p. 6, pl. 1, fig. 10). In Ecuador varieties of the *B. costata* group begin to appear in the late Oligocene and persist through the Miocene. The same appears to be true in Colombia (C. D. Redmond, private communication). The varieties *B. costata bicostata* and *B. costata interjuncta* Cushman (*loc. cit.*) seem to be confined to Miocene beds in Ecuador.

### UVIGERINELLA CALIFORNICA Cushman Plate 24, figure 19

*Uvigerinella californica* CUSHMAN, 1926, Cushman Lab. Foram. Res., Contr., vol. 2, pt. 3, p. 58, pl. 8, figs. 2, 5.

Types of this species were obtained from the Miocene of California and the range given by Kleinpell is upper Zemorrian to Luisian (1938, chart p. 150). This corresponds to its range in the sub-littoral facies of Ecuador from late Oligocene to Lower Miocene. It is sometimes the dominant

species in the early Miocene sub-littoral facies.

### UVIGERINELLA OBESA Cushman, and varieties
Plate 24, figure 20

*Uvigerinella obesa* CUSHMAN, 1926, Cushman Lab. Foram. Res., Contr., vol. 2, pt. 3, p. 59, pl. 8, figs. 3, 7.

Forms which fall within the species-group of *U. obesa* and include the variety *U. obesa impolita* have the same occurrence in Ecuador as *U. californica* (above). The occurrence of slightly different forms at different levels seems to be an effect of facies, as the order varies from one section to another. In California Kleinpell has given the range of *U. obesa, sensu lato*, as Saucesian to Luisian (1938, chart p. 151).

### PALMERINELLA spp.
Plate 25, figure 4

This anomalinid genus, characterized by an elongate slit aperture, was first recorded as *P. palmerae* in Recent material from Cuba (Bermudez 1934) and later reported from the Upper Miocene of Cuba. P. J. Bermudez has kindly supplied the information that the same species also occurs in the Upper Miocene and Pliocene of the Dominican Republic. *P. thalmanni* is a related form from the basal Miocene of Ecuador (Stainforth and Stevenson 1946, p. 563, 564, pl. 86, figs. 7–10). A very similar form submitted by P. J. Bermudez came from the middle Mohnian of California. On present evidence the genus appears to be valid as a guide to Miocene and younger beds.

### BOLIVINITA cf. QUADRILATERA (Schwager)
Plate 24, figure 8

*Textilaria quadrilatera* SCHWAGER, 1866, Novara Exped. 1857–1859, Geol. Theil, vol. 2, pt. 2, p. 253, pl. 7, fig. 103, Vienna.

Although records of its occurrence go back to the Cretaceous there is scarcely any mention of this genus in the Tertiary of tropical America. Several new species were recorded from the Upper Miocene of New Zealand by Finlay but the name *B. quadrilatera* has most frequently been used for late Tertiary and Recent specimens. LeRoy (1944, p. 84) reported it to be widely distributed in late Tertiary and Recent deposits of the Malay Archipelago, and B. Stone applies this name to a Recent species from Cuba (private communication). Specimens which occur abundantly in the neritic facies of the Upper Miocene in Ecuador, fall almost within the accepted variation of *B. quadrilatera*, differing mainly in their low angle of taper. They are absent from shallow marine and brackish sediments of similar age, which may account for lack of records in neighboring countries. *B. angelina* from the Pliocene of California differs in the more acute angle of overlap of its chambers (Church 1928, p. 265, text fig. 1). Because of the absence of such a conspicuous genus in slightly older faunas of the region it is reasonable to suggest that it may prove a useful marker for the young Tertiary.

### ELPHIDIUM spp.
Plate 24, figures 4–7

The genus ranges through the whole Tertiary, but Mio-Pliocene records far outnumber those of the Eo-Oligocene in tropical America. Although doubtless controlled by facies-changes indicative of regional emergence, it is a fact of stratigraphic significance that brackish deposits with abundant *Elphidium* spp. and "*Rotalia beccarii*" became widespread only in late Miocene time. In Ecuador occasional specimens of *Elphidium* are known from the Upper Oligocene and early Miocene, but it is only in the Middle Miocene that the *Elphidium*-"*Rotalia*" faunule appears.

### UVIGERINA PEREGRINA PARVULA Cushman
Plate 24, figure 24

*Uvigerina peregrina parvula* CUSHMAN, 1923, U. S. Nat. Mus. Bull. 104, pt. 4, p. 168, pl. 42, fig. 11.

In the late Miocene of Ecuador small specimens of *Uvigerina* appear in which the fine serrate ribs of the early portion break down to rows of spines and irregularly hispid surfaces on the later chambers. Such a form has been exactly figured from the Buff Bay beds of Jamaica (Cushman and Jarvis 1930, p. 363, pl. 33, fig. 11) but is not mentioned from the slightly older Bowden beds (D. K. Palmer 1945). There is some resemblance to *U. pigmaea* but most of the forms described under that name show a

more abrupt change from costate to hispid decoration. *U. joaquinensis* from the upper Luisian of California may be a related species (Kleinpell 1938, p. 296, pl. 17, figs. 6, 10, 11). Cushman and Todd (1941, p. 51, pl. 14, figs. 14–17) have questioned the correctness of the name applied to the Buff Bay specimens, but mention its occurence in the Miocene of Panama.

LARGER FORAMINIFERA

There is scope for more detailed research on the larger Foraminifera of Ecuador, but on the basis of published literature and manuscript reports by D. L. Frizzell, A. Martinez, R. M. Stainforth and H. E. Thalmann the principal species are known to occur in the following succession:

*Lower Middle Eocene*

The San Eduardo limestone, known in isolated patches resting unconformably on basement rocks, carries a uniform fauna, as described by Vaughan (in Sheppard 1937, p. 156 et seq.; 1945, pp. 79, 104, 112). Sheppard (1937) used the name Guayaquil in a dual formational sense and the name San Eduardo is now used for the Eocene limestone as distinct from the Cretaceous cherts (see Thalmann 1946, p. 339; Sheppard 1946, p. 496, 497). Species which occur consistently in the San Eduardo are:

*Discocyclina* (*Discocyclina*) *anconensis* Barker
*Discocyclina* (*Discocyclina*) *meroensis* (W. Berry)
*Discocyclina* (*Discocyclina*) *sheppardi* Barker
*Discocyclina* (*Asterocyclina*) aff. *rutteni* Vaughan

At a single locality *Amphistegina elliotti* Cushman and Stainforth (1946) has been recorded, a form allied to *A. lopeztrigoi* from a comparable level in Cuba.

*Upper Middle Eocene*

Limestones, lithologically like the San Eduardo, and other slightly younger reefal facies mostly contain a very different fauna. This led at first to belief in a considerable age-difference between the two faunas, but later it was suggested that a change in facies conditions, possibly lowering of water temperatures, was responsible. Very recently, limestone boulders collected by R. Walls in the Clay Pebble beds near Ancon have proved to contain an intimate mixture of the older and younger faunas. This is convincing evidence that no major hiatus separates the Middle Eocene orbitoid faunas. The younger assemblages contain no *Discocyclina* (*Discocyclina*) and only occasional *Discocyclina* (*Asterocyclina*), but are dominated by the genera *Operculinoides* and *Helicolepidina*. Species recorded include:

*Discocyclina* (*Asterocyclina*) aff. *rutteni* Vaughan
*Lepidocyclina atascaderensis* W. Berry
*Lepidocyclina peruviana* Cushman
*Lepidocyclina r. douvillei* Lisson
*Lepidocyclina vichayalensis* Rutten
*Operculinoides floridensis* (Heilprin) vars.
*Operculinoides ocalanus* (Cushman) vars.
*Helicolepidina polygyralis* Barker

*Upper Eocene*

Reefal facies are not conspicuously developed in the Upper Eocene of Ecuador, but occasional layers contain a fauna comparable in genera to the late Middle Eocene assemblages. The most diagnostic species is *Helicostegina soldadensis* and the genus *Helicolepidina* is absent. Locally *Lepidocyclina peruviana* is present in flood abundance.

*Lower Oligocene*

The early Oligocene is marked by faunas carrying *Lepidocyclina yurnagunensis* Cushman and *L. undosa* Cushman. Appearance of these species marks the base of the Oligocene in Cuba (R. H. Palmer 1945, p. 17) and in Trinidad (Renz 1942, p. 547, Cushman and Stainforth 1945, p. 10). There is a puzzling feature, however, in the abundance of *Lepidocyclina* (*Pliolepidina*) *tobleri* Douvillé which has been considered an established Upper Eocene marker whether regarded as a true species or a teratologic vairant of *L. pustulosa* (see Vaughan and Cole 1941, pp. 66, 67). On all other evidence of Foraminifera, molluscs, barnacles, etc. the Ecuadorean beds in question are Oligocene.

*Middle and Upper Oligocene*

No reefal facies are known in Ecuador of

late Lower and early Middle Oligocene age, but basal to various local transgressions in the later Oligocene are *Lithothamnion*-limestones and reefal sands. In several of these, including its type locality, *Miogypsina* (*Miclepidocyclina*) *ecuadorensis* Tan is found in abundance, accompanied by *Amphistegina* spp. and in some instances *Lepidocyclina* (*Nephrolepidina*) sp. The age of these various beds is considered late Middle to early Upper Oligocene. The reefal facies is continuous to high in the Upper Oligocene but its younger portions contain only *Amphistegina* spp.

## RADIOLARIA

Because of the wide extent of radiolarian facies in the sediments of Ecuador some attention has been paid to the stratigraphic ranges of the numerous species. It has been found that four different assemblages can be readily recognized, representative of the Upper Cretaceous, late Middle and Upper Eocene, Eo-Oligocene *sensu lato*, and Lower Miocene. Locally the Cretaceous and Eocene strata include cherts which can only be studied in thin section, but it has been found that the diagnostic species can be recognized as well in sections as in washed residues. These studies have a definite practical value, for instance near Manta where similar, almost non-foraminiferal tuffaceous shales of Eocene and Lower Miocene age are exposed in close proximity. Stratigraphic diagnosis of samples has been successfully based entirely on their radiolarian content. Thalmann (1946-b, p. 1285) reported species close to *Porodiscus circularis* Clark and Campbell and *Cenosphaera veneris* Clark and Campbell from the Upper Eocene of the Santa Elena Peninsula, indicative of correlation with the Upper Eocene of California. From material figured by Clark and Campbell (1942, pp. 12, 13, 47) the form *Spongodiscus* (*Spongocyclia*) *communis* Clark and Campbell seems close to a discoid radiolarian which occurs in abundance in the younger Eocene of Ecuador. It occurred consistently in the samples of Upper Eocene Kellogg and Sidney shales analyzed by Clark and Campbell, and it is quite distinct from the Miocene species *Spongodiscus* (*Spongodisculus*) *gigas* recorded in California by Campbell and Clark (1944, p. 27). A species typical of the Miocene in Ecuador closely resembles *Acanthosphaera* (*Raphidocapsa*) *barbati* Campbell and Clark (1944, p. 15) from the Miocene of California. The Ecuador Miocene faunas contain other members of the family Astrosphaeridae, not recorded in the Upper Eocene faunas of California (*op. cit.*). There is scope for more detailed research into the value of the fossil Radiolaria as age indicators with wide lateral ranges. Unfortunately very little progress has been made in systematic determination of the fossil Radiolaria of Ecuador.

## FACIES CONSIDERATIONS

The Tertiary sediments of Ecuador are representative of five distinct facies-provinces, with some intermingling of characteristics in boundary areas. Four of the facies-types are well known in a regional sense and can be compared with some accuracy to major bathymetric zones in the modern oceans. The fifth type is not so readily assessed, but some evidence is presented below for considering this radiolarian facies to be indicative of a cool water province.

### *Neritic facies*

Since investigations of foraminiferal faunas first started in the central American region it has been recognized that as much of the similarity between faunas from different countries is due to facies-identity as to age-identity. While it has been established that numerous individual Foraminifera, some of them listed above, are valid as regional markers for limited time-ranges, it cannot be denied that the following Eo-Oligocene formations and others less fully described carry broadly similar faunas indicative of uniform and widespread facies conditions: BARBADOS, Bissex Hill; TRINIDAD, San Fernando (including "Bamboo Clay") and lower part of Brasso; VENEZUELA, Pauji, Carapita and lower part of Agua Salada; ECUADOR, "Manta"; PANAMA, Tranquilla; COSTA RICA, Amoura; NICARAGUA, unnamed (Door 1933, p. 436); MEXICO, Chapapote, Alazan, "Papantla"; CALIFORNIA, Refugian (pro parte) and Zemorrian stages, GULF STATES, type Jackson and Vicksburg and various subsur-

RANGES OF SOME TERTIARY FORAMINIFERA IN COASTAL ECUADOR

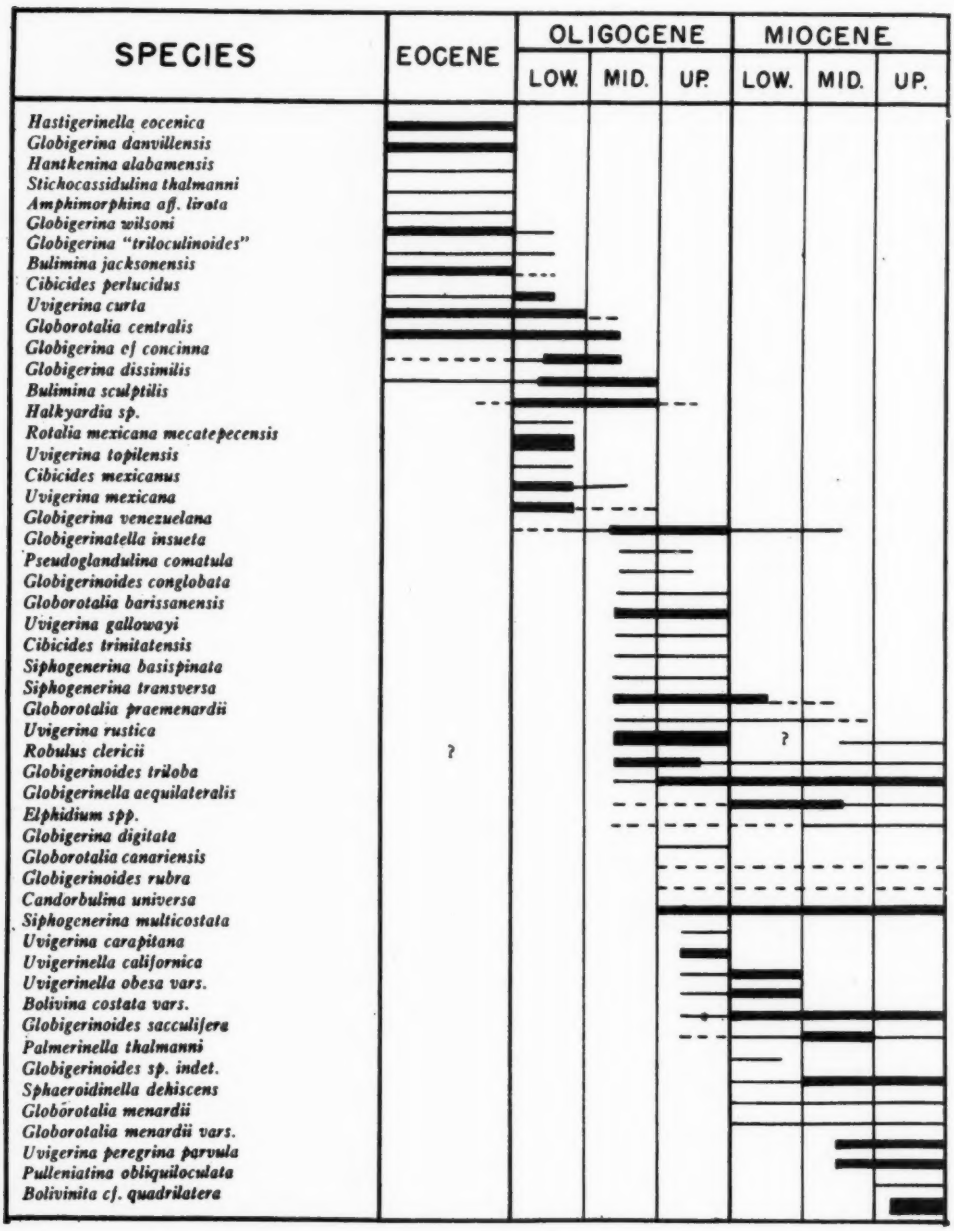



FIG. 2

face formation; CUBA, Cojimar; PORTO RICO, Ponce.

Features common to these formations are fine-textured argillaceous lithology and very rich, uniform foraminiferal assemblages. It is generally accepted that this facies marked the continental shelf area between depths at which tidal and coastal influences affected ecology and depths at which photosynthesis became inoperative at the sea-bottom owing to non-penetration of sunlight. Archibenthic facies of the *Globigerina*-ooze type are unknown in Ecuador, though some of the West Indian deposits on the fringe of the region do represent this deeper facies. The Hospital Hill and Cipero of Trinidad, the Oceanic of Barbados, and the Principe of Cuba may be cited as probably representative of the upper abyssal slope.

For the purposes of this paper the term *neritic* has been applied to the continental-shelf facies. In Ecuador various beds of Upper Eocene and Oligocene age can be referred to it. Also in the late Miocene there are remnants of a similar facies, comparable to the Bowden and Buff Bay beds in Jamaica and the Port-au-Prince beds in Haiti.

*Sub-littoral facies*

Between the inshore limits of the neritic facies and the ancient strand-lines the sediments are characterized by great variability. On average the sedimentary grade is coarser than in the neritic province and liable to rapid fluctuation both laterally and vertically. The faunas vary correspondingly. Though specimens of Foraminifera may be as abundant as in the neritic facies, the faunal lists are usually shorter and include not more than twenty or thirty species. Very often one species is numerically dominant in the assemblage, especially forms of the genera *Bolivina*, *Uvigerina* and *Siphogenerina* and of the subfamily *Discorbinae*. Molluscs and other megafossils play a more conspicuous role in these faunas than in the neritic facies.

Marine facies belonging to this group have been referred to the sub-littoral facies, which is represented at different places in Ecuador by beds of Upper Eocene, younger Oliocene and Miocene age.

*Reefal facies*

Possibly reefs should be regarded as a special case of the sub-littoral facies, though at times intimately connected with the shallower neritic facies. They can be divided into reef limestones and reef sands. The former are biochemical precipitates of lime in shallow tropical seas. In Ecuador algal-orbitoid limestones exist of Middle Eocene and younger Oligocene to basal Miocene age. The second type of reef deposit is of the sand-bar type, characterized by coarsely clastic lithology and a rich fauna of specialized organisms, especially orbitoids and sessile forms. Such deposits are known in Ecuador of late Middle Eocene and Oligocene age.

*Brackish facies*

On the shoreward fringe of the marine environment low salinity due to river discharge or lagoonal conditions governs the specialized brackish facies. Because of the inevitable proximity of land, carbonaceous matter is usually conspicuous in the sediments, which tend to be of a variable but rather coarse littoral type. Organisms of many phyla have adapted themselves to this environment, the principal Foraminifera being *Elphidium*, the Miliolidae and the form usually referred to *Streblus* ("*Rotalia*") cf. *beccarii*. In Ecuador there are local brackish-facies deposits in the Upper Eocene, the late Oliocene and the Miocene. Probably the Pliocene was a time of widespread brackish facies, but Plio-Pleistocene chronology has not been accurately worked out.

*Radiolarian facies*

This name is applied to a distinctive facies which was recurrent from the mid-Eocene to mid-Miocene in Ecuador. If only for its considerable local extent, at times dominating the whole marine environment, it deserves attention, but more significant is its affinity to various *Thyasira*-bearing deposits in parts of the western seaboard of the United States. The conclusion reached in Ecuador is that this facies marked the path of cold ex-polar currents comparable to the present-day Humboldt drift. A subsidiary conclusion is that the vertical distribution

of the molluscs *Thyasira*, *Acila*, *Pleurophopsis*, *Vesicomya*, etc. was governed by the existence of this cool-water province and that this suite was well-established in Upper Eocene time. It does not necessarily follow that same is true of the disputed Eo-Oligocene in California, Oregon and Washington, but the parallelism is suggestive.

The distinctive features of this facies are expressed below in a few objective statements, followed by inferential reasoning on which the above conclusions are based.

(1) The dominant lithologic type is finely tuffaceous shales, partly chertified, but conglomeratic sandstones may be interbedded as at Ancon Point and along the coast west of Manta. Most of the clastic sediments in Ecuador are tuffaceous to some degree, but those of the radiolarian facies are markedly so.

(2) The characteristic microfauna contains an abundance of Radiolaria with only few Foraminifera, the latter being usually of long-ranging eurybathic species. An exception is the pelagic *Hastigerinella eocenica* which is rather common in the Upper Eocene radiolarian facies but scarce in synchronous neritic facies.

(3) The characteristic megafauna consists of a limited suite of molluscs typified by the genera *Thyasira*, *Acila*, *Pleurophopsis*, *Vesicomya* and *Lucina*. It is generally agreed that as a group these forms indicate a cold marine environment.

(4) This facies is always developed to the west, presumably ocean-ward, of any normal marine facies existing at the same time. The lateral transition is abrupt in the faunal sense though not strongly marked lithologically. At different places and levels transition is seen into normal neritic, sub-littoral, reefal and near-brackish facies.

(5) Both the neritic and sub-littoral facies in proximity to the radiolarian facies are abnormal in respect to pelagic Foraminifera. In some cases the sub-littoral facies contains a phenomenal abundance of *Globigerina*, etc., whereas the neritic facies near its transition into the radiolarian facies is almost devoid of these normally abundant forms.

(6) The Tertiary basins of Ecuador preserved their general form from mid-Eocene to late Oligocene time, as shown by the paleogeographic distribution of the depth-controlled facies already discussed. Paleogeographic maps show clearly that during times of co-existence of normal and radiolarian marine facies the most normal marine facies existed to the north and east of major sea-floor highs. "Normal" is used here in reference to overall frequency of Foraminifera and proportion of pelagic forms, as compared with similar facies in regions where the radiolarian facies was not developed. The eastern margin of the radiolarian facies ran tangential to and west of sea-floor highs: normal marine facies were developed in the lee of these highs: intermediate areas contained transitional facies, abnormal (as under 5 above) in the distribution of pelagic Foraminifera or semi-sterile.

(7) The maximum eastward extent of the radiolarian facies was reached at times of general subsidence, especially in Upper Eocene and early Miocene time.

On this evidence the radiolarian facies is not a bathymetric zone in the normal sense (from statement 4 above). The molluscan evidence indicates that low water temperature was a controlling factor (3), and this suggestion is supported by the abnormal distribution of pelagic Foraminifera (2, 5) since, as a whole, the pelagic Foraminifera favor warm waters (as in the Gulf Stream) and their inhibition or mass destruction at the fringes of the radiolarian facies can be taken as a sign of hostile cold conditions. The facts that the radiolarian facies-province included shallow water sediments (1) and that the pelagic as well as the benthonic Foraminifera were inhibited (2,5) indicates that surface waters were cold. The development of normal tropical facies beyond the eastern limits of the radiolarian facies (4) indicates that the low temperatures can only be attributed to ocean currents. A parallel to the Humboldt current here suggests itself and receives confirmation by the limitation of normal marine facies to positions to the north and east of sea-floor barriers and by the existence or in-

fluence of the radiolarian facies in unsheltered areas (6). Following this interpretation it would be natural for the cold province to encroach eastwards at times of subsidence (7) when physiographic barriers had been lowered, or in effect had retreated eastwards. The late Oligocene subsidence is not marked in northern Ecuador by eastward advance of the radiolarian facies, rather the reverse, a fact explained by deposition of a massive fan of late Eocene and early Oligocene sediments to the south.

Not explained in the above synopsis is the abundance of Radiolaria (2). Taliaferro (1943, pp. 147–150) has discussed comparable facies in the Franciscan-Knoxville of California, and has associated radiolarian cherts with excess of silica due to nearby volcanic activity. In the case of the Ecuador Tertiary beds the same explanation might appear feasible, as the growth of the Andes was accompanied by volcanic activity and most of the sediments are appreciably tuffaceous (see Sheppard 1937, p. 93; Thalmann 1946-b, p. 1285); but the existence of normal marine facies between the Andes and the belt-province of the radiolarian facies is an insurmountable objection. By the geosynclinal theory postulated by Olsson (1932, pp. 51–58) and earlier authors a Tertiary land-mass is assumed to the west, and volcanic activity in that area could be taken as the source of excess silica. This idea is tenable but it is more hypothetical than the cold-current theory and fails to account for the specialized molluscan suite and the peculiar disposition of the radiolarian facies. Also it would seem that any facies-province governed by the existence of a western land mass would move westwards during regional subsidence, whereas the reverse was true of the radiolarian facies. A much simpler explanation is that no other organisms could tolerate the low water temperatures (or secondary effects such as destruction of phytoplankton and elimination of photosynthesis) and hence the Radiolaria thrived in abundance. It is not certain that tuffaceous lithology was directly related to the biologic characteristics of the radiolarian facies, though the records from Oregon, California and Ecuador all point to some connection. Not to be overlooked is the pronounced effect of cold oceanic currents on the adjacent mainland. The product is arid desert and it is possible that the weathering products in such areas might differ from the clay colloids of moister areas.

Of the regional scale it may be observed that the marked change in direction of the South American coast-line near Latitude 1° South reflects basement features of the type claimed above to have deflected the cold oceanic currents. The basement trend swings sharply from a northeasterly to a southeasterly direction, and areas to the south should clearly be less protected from north-bound currents than areas to the north. This can be seen to be true for the Upper Eocene, when a faunally rich *Hantkenina*-bearing neritic facies developed in sheltered patches in northern and central Ecuador, but is represented only by impoverished replicas in southern Ecuador and northern Peru. Also in the younger Oligocene there is a sharp line of faunal distinction between beds with the rich "Manta" (Caribbean-type) fauna in central and northern Ecuador and the Heath-type beds in southern Ecuador and northern Peru with a fauna recognizably related but relatively poor in species. The *Thyasira-Pleurophopsis* suite of molluscs is well known in the Heath of Peru (Olsson 1931, pp. 21, 22) but has never been found in beds of the same age in Ecuador.

In manuscript reports D. L. Frizzell has suggested cold-water control to account for vagaries in the distribution of *Discocyclina* in the Peruvian Eocene. The suggestion matches the more generalized scheme of cold oceanic currents and can be applied to the abrupt disappearance of *Discocyclina* s. s. in the mid-Eocene of Ecuador.

In Ecuador the radiolarian facies was in existence from late Middle Eocene to mid-Miocene time. During almost the whole of this period it extended east of the present coastline, the easternmost extent varying with paleogeographic changes. For a brief interval during the later Oligocene the facies receded west of the present coastline, but its presence can be deduced from a lack of pelagic Foraminifera in unsheltered parts of the neritic facies which replaced it.

## TIME-SPACE DISTRIBUTION OF BIOSTRATIGRAPHIC UNITS IN ECUADOR

The loose meaning attached here to a biostratigraphic unit is a bed which on faunal grounds can be determined as to age and facies. The purpose of this section is more to serve as a guide to collecting localities than to give a summary of paleogeography, except where necessary to substantiate statements on facies relationships. Some units are designated by a place name and a lithologic term. This does not suffice to define new formations and members, but in most cases the place name has been so used in private reports of the International Ecuadorean Petroleum Company and is suitable for retention in the future for further discussion of the stratigraphy of coastal Ecuador. Formation names introduced by Sheppard (1937) and still considered valid are used for the southwestern region.

### CRETACEOUS

See Thalmann (1946) for a comprehensive summary.

### (?) EARLY TERTIARY

A thick series of indurated shales including sandstones and conglomerates underlies the Middle Eocene of southwestern Ecuador and is the principal outcropping formation of the Cerros de Estancia. Fossil evidence is almost negligible but a Lower Eocene age is commonly assumed because of its position between known Upper Cretaceous and Middle Eocene strata. Thalmann (1946-a, pp. 346, 347; 1946-b, p. 1235) considered the lower part of the series to be Paleocene, but there is no strong evidence against placing the whole unit in the Danian.

### LOWER MIDDLE EOCENE

The San Eduardo limestone, with its characteristic *Discocyclina* fauna, can most readily be examined at the quarries of the Fabrica de Cemento Nacional "Rocafuerte" a few kilometers west of Guayaquil. The limestone extends in strike prolongation from these quarries along the southern flank of the Cerros de Chongon. It pinches out some 40 km. west-northwest of Guayaquil but reappears patchily on structural highs as far as the extreme north of the coastal area, e.g. Punta Ostiones. No other facies of the same age has been recognized.

### UPPER MIDDLE EOCENE

*Reef Facies*

Limestones with the significant *Discocyclina-Operculinoides-Helicolepidina* suite are only known as boulder remnants in the Clay Pebble beds. R. Walls drew attention to a concentration of this material near the narrow-gauge railway-cut just north of Ancon. The matrix of the Clay Pebble beds of the Ancon area and occasional sands in the Socorro contain a similar but slightly younger assemblage with no *Discocyclina* s. s. Elsewhere the same fauna occurs in the Javita limestone, developed patchily along the southwest flank of the Cerros de Colonche. Lithologically and by apparent strike prolongation the outcrops in several tributaries of Rio Nuevo are likely to be confused with the San Eduardo. Similar limestones, some with *Helicolepidina polygyralis* in rock-forming abundance are known in the Manta area and on Rio Santiago in the north, but the exposures are obscure or difficult of access. The Punta Tinosa orbitoid grits, 12 km. west of Manta, are of the same age.

*Marine facies*

The Socorro formation of the south is of this age, but tends to carry undiagnostic arenaceous microfaunas except in its orbitoid facies. A radiolarian facies of the same age exists but is not readily distinguished from the more extensive developments in the Upper Eocene.

### UPPER EOCENE

Upper Eocene deposits are widespread and readily segregated into facies-types, so that for the first time an overall impression of facies relationships can be gained.

*Neritic facies*

A long strip of Upper Eocene beds in normal neritic facies is exposed along the upper courses of Rios Grande, Zapallo Grande and Santiago, major tributaries of Rio Cayapas, in northern Ecuador. These

may be termed the Zapallo shales. No other surface exposures of the same type are known, but an identical subsurface unit has been encountered in the Manta area. In southern Ecuador the nearest approach to it is seen in the *Hantkenina*-bearing Jusá shales exposed (under alluvium) some 15 km. E. S. E. of Colonche, and also known in subsurface. This southern facies is semi-sterile, strongly influenced by the radiolarian facies to the west.

*Sub-littoral and brackish facies*

In the south, to the east of the Cerros de Estancia, the later Eocene was marked by an influx of clastic material. The sedimentation was variable and included formation of the Zapotal molluscan sands exposed along the eastern border of the Cerros de Estancia northwards from Zapotal, at Posorja at the mouth of Rio Guayas, and elsewhere. These sandstones are non-foraminiferal, but associated shales known in subsurface yield shallow marine and brackish microfaunas.

*Reefal facies*

True reefal facies are scarce in the Upper Eocene, but the Salanguillo orbitoid sands exposed some 15 km. east-northeast of Colonche yield almost a one-species assemblage of *Lepidocyclina peruviana*. This development is on the same trend as the older San Eduardo and Javita limestones, from which it appears that the Eocene reef-facies fringed an old high and merged westwards into deeper water facies. Erosion has cut down to Middle Eocene levels, leaving only remnants of the Upper Eocene reefs. Around Punta Mambra on the south coast the Seca shales contain occasional layers with a *Lepidocyclina-Operculinoides-Helicostegina* assemblage.

*Radiolarian facies*

In extent and uniformity the radiolarian facies dominated the Upper Eocene marine environment. The Seca as described by Sheppard and the San Mateo tuffaceous shales east of Punta Tinosa near Manta typify this unit. Farther north the beds have been chertified to a large extent and have been confused with the Cretaceous Guayaquil chert (see Thalmann 1946-a, pp. 343, 344). The basic fauna is a flood of Radiolaria and a few *Hastigerinella eocenica* and *Globigerina wilsoni*. There is a distinct tendency for gradation into a normal neritic facies, upwards as at Valdivia on the coast northwest of Colonche and in subsurface near Manta, and laterally eastwards between Ancon and Punta Mambra on the southern coast, in the Jusá shales, and between the Galera peninsula and the upper Rio Cayapas.

LOWER AND EARLY MIDDLE OLIGOCENE

*Normal marine facies*

Overlying the neritic Upper Eocene there is a belt of early Oligocene beds exposed along the upper courses of Rios Grande, Zapallo Grande and Santiago. The vicinity of Playa Rica on Rio Santiago is a good study area. These Playa Rica beds consist of alternating orbitoid sandstones, with a rich reefal fauna, and shales with a normal neritic fauna. Correlative beds are exposed to the north between Rios Verde and Maté, but there is no reefal element here and the neritic facies is semi-euxinic, showing influence of the radiolarian facies to the west. In the whole of the northern Lower Oligocene there is a distinct tendency for transition upwards to radiolarian facies conditions. Farther south a single exposure is known of the Lower Oligocene reef facies, at Punta Mal Paso 4 km. west of Manta.

*Brackish facies*

The Zapotal depositional cycle of the south ended with brackish beds of presumed Lower Oligocene age. Because of differences in facies an accurate comparison cannot be made with the Playa Rica faunas, but the few specimens of *Globigerina* present, the appearance of *Bulimina sculptilis* in place of *B. jacksonensis* in slightly older beds, and other species unnamed but useful in local zonation all suggest an early Oligocene age. There are no good exposures of this unit but it is present consistently in the subsurface.

*Radiolarian facies*

The existence of this facies in the Galera peninsula might be assumed from the westward passage of typical Playa Rica to the semi-euxinic facies on Rio Verde, and sub-

surface evidence substantiates this assumption. No surface exposures are available owing to the combined effects of pre-Miocene and sub-Recent erosion.

### MID-OLIGOCENE

The tendency for the early Oligocene neritic facies to grade upwards into a radiolarian facies culminated in the local deposition of mid-Oligocene tuffaceous shales between Rio Ostiones and the lower Esmeraldas. In unpublished reports the name Chumundé ash-beds has been applied to these strata, from exposures on Rio Chumundé, a tributary to the Verde. They correspond in age to the brief hiatus marked by local unconformities at the base of the younger Oligocene formations. In the south, east of Cerros de Estancia, where the evidence is not destroyed by erosion, static non-depositional conditions seem to have marked completion of the Zapotal cycle.

### LATE MIDDLE AND UPPER OLIGOCENE

In the northern area a brief mid-Oligocene spasm caused uplift to the northeast, following which there was general subsidence of the whole of western Ecuador during the late Middle and Early Upper Oligocene. In this interval sub-littoral sediments first transgressed the basinal margins and were in turn overstepped by neritic facies. In mid-Upper Oligocene isostatic equilibrium was achieved and the remaining Oligocene was marked by a process of basinal infill, with rapid westward advance of tongues of clastic sediments.

*Neritic facies*

The "Manta" fauna described by Galloway and Morrey (1929) is typical of the younger Oligocene neritic facies, and almost certainly came from Jaramijo Bay, 9 km. east of Manta. A better type area, because of the more complete section, centers on the town of Tosagua. The Rio Esmeraldas and its tributaries, such as the Viche, cut through extensive exposures of correlative beds. Lithologically there is no difference between the Tosagua and Viche shales and their benthonic foraminifera are the same, but the Viche is much richer in pelagic forms. Pelagic Foraminifera also are abundant in similar shales between Manta and Jipijapa. As already mentioned, this peculiarity is related to shelter of the Viche and Jipijapa areas from the effects of cool currents.

In the south the shales overlying the Zapotal, exposed north and south of Dos Bocas, carry comparable neritic assemblages but faunal densities are lower and there is a rhythmic interbedding of almost barren tuffaceous shales, shales with dominantly arenaceous Foraminifera and shales with neritic facies assemblages. F. V. Stevenson, who made detailed studies of subsurface control sections, attributed this variability to periodic lowering of water temperatures. Owing to deep weathering it is difficult to locate surface exposures of rich foraminiferal material, though the unit is widely exposed in gullies and artificial cuts.

*Sub-littoral facies, including reef accumulations*

The initial transgression of late Middle Oligocene sediments was marked in the north by sandy beds, partly conglomeratic, typified by an abundance of euhedral grains of volcanic minerals. Locally they contain *Miogypsina-Lithothamnion* reefs. In late Upper Oligocene the process of basinal infill was initiated by deposition of very similar sediments, encroaching transitionally westwards over the neritic Viche shales. The final stage of basinal infill was deposition of fine-textured topset shales above the fans of foreset silts and sands, but this phase of sedimentation took place mainly in the Miocene. The older transgressive beds and the younger foreset beds of the north are usually referred to the Angostura formation, from a molluscan locality on Rio Santiago.

The lithologic and facies succession is much the same over the whole area east of Rio Esmeraldas, except that there are limits respectively to east and west of which the neritic and earlier sub-littoral facies were not developed. In the time sense, however, a facies change which marks basal Miocene in one place may be low in the Upper Oligocene at another. The faunal succession at any point reflects the order of facies changes much more closely than the small age-differences involved, and failure to appreciate this led to considerable confusion in early attempts at foraminiferal zonation.

The difficulty was overcome by detailed attention to the ranges of pelagic Foraminifera.

Farther south a sub-littoral facies of Angostura type is gradationally transgressive over the Tosagua shales. The Hacienda San Agustin, 20 km. north of east from Bahia, has been considered the type area. The San Agustin sands are clearly equivalent to the younger (infill-phase) Angostura.

In southwestern Ecuador there are remnants of *Miogypsina*-reefs which mark the initial transgression of the younger Oligocene. A well-known locality is at San Pedro near Valdivia, the type locality for *Miogypsina ecuadorensis* Tan (see Barker 1932). A less-known locality marked by boulder-float remnants of a *Miogypsina*-limestone lies around the trail between the two main tributaries of Rio Jusá, some 10 km. E. S. E. of Colonche.

*Brackish facies*

This facies was of negligible extent in the younger Oligocene, but is occasionally encountered in Angostura beds on the fringes of the northern basin.

*Radiolarian facies*

The Chumundé tuffaceous shales are succeeded abruptly by normal neritic Viche shales which continued to be deposited uniformly until late in Oligocene time. Sterile and euxinic conditions then began to appear in the Galera peninsula and Punta Ballena areas, but not farther east. As already discussed, the local absence of pelagic Foraminifera in the Tosagua shales is considered another indication of a cool water province in the west.

LOWER AND EARLY MIDDLE MIOCENE

Remnants of the Oligocene neritic facies were rapidly obliterated by shallow marine sediments in the early Miocene. In the north the process of basinal infill continued as already indicated. The youngest foreset beds and a *Siphogenerina*-rich facies transitional to the topset beds are generally early Miocene in age, but most of the early Miocene sediments belong to the topset beds, named the Onzole shales from excellent exposures along the upper course of the Onzole. Topset deposition had already started in the late Oligocene of the lower Cayapas area, but these Onzole shales become progressively younger towards the Galera peninsula where they overlie foreset beds of early Miocene age.

Farther south, in the Manta-Tosagua region, there was evidently uplift and erosion at the end of Oligocene time, as the Onzole-like Charapotó shales are locally unconformable on older beds. A sharp boundary can be drawn between radiolarian facies to the west and foraminiferal facies to the east within the Onzole and Charapotó shales along the present coastal strip. As in the Oligocene shales, pelagic Foraminifera are common to abundant in the Jipijapa and Onzole areas but lacking in the Tosagua area. In the early Middle Miocene of the Rio Onzole area the shales often contain floods of pelagic Foraminifera abnormal for a sub-littoral to brackish facies, and these have been regarded as death-assemblages on the fringe of a cold-water province.

In southern Ecuador the subneritic facies of the Oligocene Dos Bocas shales graded upwards into shallow marine deposits which rapidly assumed brackish characters in the early Miocene. Subibaja and Zacachun, 60 km. due east of Guayaquil have been considered type areas.

The final stage of basinal infill in the north is seen in brackish beds with a "*Rotalia*"-*Elphidium* assemblage, lithologically part of the Onzale shales of early Middle Miocene age. Outcrops are known at the headwaters of Rios Lagarto and Lagartillo which flow into the ocean near Punta Ostiones, and also farther south, on Rio Quinindé 35 km. south of the town of the same name.

LATE MIDDLE AND UPPER MIOCENE

Most sediments of this age are undistinctive brackish-water deposits, but there was evidently substantial subsidence along the present coastline because a rich neritic facies developed. Remnants of these beds have escaped pre- and post-Pleistocene uplift and erosion and can be studied along the coast between Charapotó and Jama, in the Galera peninsula, especially near Punta Gorda, and in other patches. A. Martinez (private report) has established four foraminiferal zones which appear to be valid over

the whole known extent of this unit. Because of lithologic similarity this neritic facies is usually included in the Borbón silt, typified by weakly foraminiferal strata exposed on the lower Rio Onzole south of the town of Borbón.

### PLIOCENE AND PLEISTOCENE

Shallow marine and brackish sediments on Puná Island carry Foraminifera of facies significance but little value in age determination. These and similar beds known under the thick alluvium of the Rio Guyas have been referred to the Pliocene on molluscan evidence. The Tablazo is a shallow marine deposit of Pleistocene age covering much of the present coastal fringe. It carries a very rich molluscan fauna but no Foraminifera of special age significance.

## REGIONAL CORRELATION

Despite the initial difficulties of distinguishing between the time-elements and the facies elements in the Tertiary microfaunas, it has become steadily more apparent that, used judiciously, the fossil Foraminifera provide a reliable base for regional correlation in the central American region. The bottom-living forms include numerous species and species-groups restricted to the same limited life-range over great areas. Earlier in this paper some evidence is given for believing that the planktonic forms are still more valuable because their distribution was scarcely affected by facies differences. Represented in Ecuador are five foraminiferal stages which can be recognized on a regional scale, as follows:

(1) An Upper Eocene stage: Upper limit marked by the extinction of *Amphimorphina* spp., *Bulimina jacksonensis*, *Discocyclina* spp. (s.l.), *Globigerina danvillensis*, *Hantkenina* spp., *Hastigerinella eocenica*, *Helicostegina soldadensis*.

(2) An earlier Oligocene stage: lower limit marked by extinction of the species listed above and by first appearance of *Bulimina sculptilis*, *Globigerina venezuelana*, *Halkyardia* sp., *Lepidocyclina undosa*, *L. yurnagunensis:* upper limit at or above the level of extinction of *Cibicides perlucidus*, *Globigerina* cf. *concinna*, *G.* "*triloculinodes*," *G. wilsoni*, *Globorotalia centralis*, *Halkyardia* sp., *Uverigerina curta*, *U. topilensis:* species useful as guide-fossils, but also ranging a short way into the next higher stage, are *Cibicides mexicanus*, *Globigerina dissimilis* and *Uvigerina mexicana*.

(3) A later Oligocene stage: lower limit above the level of extinction of species listed above and at or below the first appearance of *Candorbulina universa*, *Cibicides trinitatensis*, *Globigerina digitata*, *Globigerinatella insueta*, *Globigerinella aequilateralis*, *Globigerinoides conglobata*, *G. rubra*, *G. sacculifera*, *G. triloba*, *Globorotalia barissanensis*, *G. canariensis* *G. fohsi*, *G. praemenardii*, *Miogypsina* spp., *Pseudoglandulina comatula*, *Robulus clericii*, *Siphogenerina basispinata*, *S. multicostata*, *S. transversa*, *Uvigerina carapitana*, *U. gallowayi*, *U. rustica*, *Uvigerinella californica*, *U. obesa:* upper limit at or above the level of extinction of *Cibicides mexicanus*, *C. trinitatensis*, *Globigerina dissimilis*, *Globigerinatella insueta*, *Globigerinoides conglobata*, *Globorotalia barissanensis*, *G. fohsi*, *Pseudoglandulina comatula*, *Siphogenerina basispinata*, *Uvigerina mexicana*.

(4) A lower Miocene stage: lower limit marked by extinction of the species listed above and by first appearance of *Globorotalia menardii*, *Sphaeroidinella dehiscens*, *Palmerinella* spp.

(5) A younger Miocene stage: less clearly defined but typified by floods of *Elphidium* spp. and *Streblus* ("*Rotalia*") cf. *beccarii* in the shallower water facies and by *Bolivinita* cf. *quadrilatera*, *Uvigerina peregrina parvula*, multicamerate varieties of *G. loborotalia menardii* and *Pulleniatina obliquiloculata* in neritic facies.

The master zonation in Ecuador is based on these species, and their order of appearance and extinction is so consistent in the published biostratigraphic literature of the Central American region that their value in zonation may be taken as empirically proved. The very few instances in which any of these species have been recorded out of position can fairly be called in question in face of the cumulative evidence of other areas. The only instances known to the writer are the following:

(a) The lower Oligocene Alazan fauna of

Mexico, as described by Nuttall (1932), is a close equivalent of the Lower Oligocene Playa Rica of Ecuador and as a whole there is no question that the age was correctly given. There are, however, passing references to species which are regarded elsewhere as rigid markers for younger stages, including *Cibicides trinitatensis* (l. c., p. 33), "*Uvigerina auberiana*" (*U. rustica*) (p. 21), *Pseudoglandulina comatula* (p. 16) and *Globorotalia menardii* (p. 29). Also mentioned is *Amphistegina lessoni*, usually found in the younger Oligocene and Miocene. Dorr (1933, pp. 432, 435) listed the Foraminifera of what he called "a representative part of the middle and upper Alazan formation" from shale samples in the vicinity of Papantla, Vera Cruz, Mexico. This Papantla fauna contains none of the species listed by Nuttall as characteristic of the lower Alazan, but it does contain several species considered markers for the younger Oligocene foraminiferal stage (*Globorotalia canariensis*, *Robulus clericii*, *Siphogenerina multicostata*, *S. transversa*). Dorr was therefore probably right in correlating his Papantla fauna with the Aguide fauna of Venezuela and the Manta fauna of Ecuador, but wrong in correlating it with the true Lower Oligocene part of the Alazan. Hedberg (1937, p. 690) quotes Thalmann as mentioning "Papantla beds" referred to the Lower Miocene. The point seems to be fairly established that both older and younger Oligocene beds of similar facies are exposed in the general area of Tuxpan. From this it might follow that Nuttall's material, while dominantly Lower Oligocene, accidentally contained a small amount of the younger material. The opinion of paleontologists with experience in the area would be useful in clarifying this important point.

(b) The fauna of the Carapita formation of Venezuela was discussed in detail by Hedberg (1937), who carefully assessed the facies problem before correlating the middle zone with the Upper Oligocene as this is generally understood. Later Franklin (1944) described the Carapita fauna from unspecified outcrops in the vicinity of Rio Oregano and without discussion of previous conclusions claimed a Lower Oligocene age by correlation with the Alazan of Mexico and the Finca Adelina of Cuba. Of the species listed above as stage-markers on a regional scale Franklin listed the following: *Robulus clericii* (p. 309), *Pseudoglandulina comatula* (p. 312), *Uvigerina mexicana* (p. 315), *Globigerina concinna* (p. 317) and *Globigerinella aequilateralis* (p. 318). Hedberg confirms the first two of these and refers to *Globigerinella* sp., but whereas he refers to a form tentatively assigned to *Globigerina concinna* as "fairly common," the *G. concinna* figured by Franklin is described as occurring "only rarely." Franklin's form seems identical with *G.* cf. *concinna* of the present paper, but the discrepancy in frequency suggests that it is not the same as Hedberg's unfigured form. Hedberg did not refer to *Uvigerina mexicana* in the Carapita but it occurs low in correlative beds in Trinidad. Apart from the species discussed above, Franklin's distribution chart (pp. 302, 303) lists many long-ranging facies-controlled species and many that are simply Oligocene, no more typical of the older than of the younger stage. Still other species used as evidence of correlation with the Alazan are insufficiently distinct from younger Oligocene forms, examples being *Gaudryina jacksonensis* of the Alazan and *Gaudryina jacksonensis irregularis* Cushman and Renz of the Agua Salada, or *Verneuilina mexicana* of the Alazan and *Verneuilina cyclostomata* Galloway and Morrey of the Manta. In short Franklin's evidence for Lower Oligocene age of the fauna he lists is unconvincing. Both Hedberg and Franklin have commented on the great thickness of the Carapita formation, and the bulk of Hedberg's conclusions were based on the middle zone. It is possible that species such as *Globigerina* cf. *concinna* occur in the lower parts, but as a whole Franklin's fauna does not differ appreciably from Hedberg's and both represent the younger Oligocene.

(c) The Cojimar fauna of Cuba was treated by D. K. Palmer (1940–41) as a single zonal unit of Upper Oligocene age. It is noted, however, that in the accompanying distribution chart there appears to be a younger zone marked by the extinction of *Globorotalia fohsi* and the appearance of *G. menardii* and *Sphaeroidinella dehiscens*. In other areas this faunal change is treated as diagnostic for the base of the Miocene. This question has been discussed in correspondence with Mrs. D. K. Palmer and Dr. P. J. Bermudez, who adhere to the view of an Upper Oligocene age, although Mrs. Palmer states "I still consider the Cojimar formation fauna to be late Oligocene in age with some evidence of transition to the Lower Miocene in its uppermost part." Samples of the upper Cojimar kindly submitted to the writer by P. J. Bermudez show no evidence of Miocene age. Heavy-keeled *Globorotalia menardii* is not apparent, though a form close to *G. praemenardii* is fairly common, whereas the Oligocene species *Globorotalia barissanensis* and *Globigerina digitata* are both present.

Turning to Ecuador, the *Discocyclina* fauna of the San Eduardo can be directly correlated with the Upper Scotland formation of Barbados on the evidence of abundant *Discocyclina anconensis* and the presence of *Amphistegina* of the *A. lopeztrigoi* group (*A. senni* in Barbados and *A. elliotti* in Ecuador). Vaughan (1945, p. 21) stated "The foraminiferal fauna of the Upper Scotland formation is obviously Middle Eocene, and it may be considered the type Middle Eocene larger foraminiferal fauna of America." Vaughan also noted points of similarity between the faunas of the Upper Scotland, the Middle Eocene Guayabal and beds near Yecuatla in Mexico, and the Middle Eocene of Cuba and Florida.

The *Operculinoides-Lepidocyclina-Helicolepidina* assemblage of the Clay Pebble beds, Socorro sands and Javita-type limestones is typified by *Helicolepidina polygyralis*, a form which Grimsdale considered Middle Eocene, ancestral to the Upper Eocene *Helicostegina soldadensis* (Barker and Grimsdale 1936, fig. 4, p. 244; Grimsdale in Vaughan and Cole 1941, p. 86). Berry recorded similar faunas from the Eocene of northern Peru (for references see Ellis and Messina, Catalogue of Foraminifera, Vol. 29, Bibliography, p. 17). In orbitoidal sands near Ancon occurs a species of *Dictyoconus*, a genus typical of the Eocene, usually Middle Eocene.

The Zapallo shales are typical of the Upper Eocene neritic facies of the region and contain such time-markers as *Amphimorphina* spp., *Bulimina jacksonensis*, *Globigerina danvillensis*, *Hantkenina alabamensis*, *H. brevispina* and *Hastigerinella eocenica*. The foraminiferal assemblage as a whole can be compared with the Chapapote of Mexico (Nuttall 1930), the Tranquilla of Panama (Coryell and Embich 1937), the Pauji of Venezuela (Nuttall 1935), the San Fernando of Trinidad (Renz 1942), the Gulf Coast Jacksonian (Cushman 1935) and parts of the Refugian of California and Oregon (Kleinpell 1938, etc.). The reefal layers of the Seca are characterized by *Helicostegina soldadensis*, first recorded from the Upper Eocene of Trinidad and mentioned by Frizzell in unpublished notes on the younger Eocene of Peru. By local zonation based on Radiolaria and Foraminifera the Seca shales and San Mateo tuffaceous shales fall within the Upper Eocene foraminiferal stage. The presence of *Hastigerinella eocenica* and *Globigerina wilsoni* in these units and the presence of a Zapallo-type assemblage high in the San Mateo near Manta are substantiating evidence. *Stichocassidulina thalmanni* is useful in correlating the Seca and San Mateo with the Chira of Peru, where this species also occurs within the life range of *Hantkenina*. Thalmann (1946-b, p. 1285) has correlated the radiolarian faunas with the assemblages of the Upper Eocene Sidney and Kellog shales of California.

In its neritic facies the Playa Rica fauna is five-sixths identical with the Zapallo assemblage, but the differences are significant and show that the Playa Rica falls within the early Oligocene stage. The Upper Eocene markers disappear and in their place occur *Bulimina sculptilis*, *Rotalia mexicana mecatepecensis*, *Uvigerina topilensis*, etc. *Globigerina wilsoni* becomes scarce but *G. concinna*, *G. dissimilis*, *G. "triloculinoides"* and *Globorotalia centralis*

are plentiful. In the reefal facies *Lepidocyclina undosa, L. yurnagunensis, Halkyardia* sp. and *Cibicides perlucidus* are locally common. Presence of the Upper Eocene *Lepidocyclina* (*Pliolepidina*) *tobleri* is an unexplained anomaly. There is a clear-cut resemblance to the Lower Oligocene Alazan of Mexico (Nuttall 1930, not Dorr 1933) and also to the younger San Fernando of Trinidad, the Finca Adelina of Cuba and the Ponce (part) of Porto Rico.

The Viche and Tosagua shales are represented by the Manta fauna of Galloway and Morrey, first assigned to the Upper Eocene but later placed in the Miocene by Cushman (1929). Currently the fauna is accepted as typical of the younger Oligocene foraminiferal stage, closely comparable to those of the Carapita and lower Agua Salada of Venezuela, the lower Brasso of Trinidad, the Bissex Hill of Barbados, the Ponce (part) of Porto Rico, the Cojimar of Cuba, the Zemorrian of California, the Papantla beds of Mexico (Dorr 1933), the Amoura of Costa Rica, unnamed beds in Nicaragua (Dorr 1933) and others. Distinction from the older Oligocene and early Miocene is based on the faunal criteria already discussed. It is noteworthy that in southern Ecuador and northern Peru the similarity of the younger Oligocene faunas to this Caribbean assemblage is not so pronounced and becomes remote towards the end of the Oligocene epoch.

The sublittoral Angostura is equivalent in age to the neritic Viche and Tosagua, but the benthonic Foraminifera are entirely different. The distribution of pelagic Foraminifera is the same in both facies, *Globigerina dissimilis* vanishing and *Globigerinatella insueta* appearing near the base, *Globigerina digitata, Globigerinoides conglobata* and *Globorotalia barissanensis* disappearing near the top. The benthonic assemblages of the Angostura most resemble those which began to appear in the Zemorrian and dominated the Saucesian of California. Typical species are *Uvigerinella californica* vars. and *U. obesa* vars. There is a distinct resemblance, which becomes even more pronounced in the overlying Onzole, to Recent faunas dredged in the cold water province along the western coast of America (Cushman 1927).

The base of the Miocene falls within the older Onzole or the younger Angostura according to locality. It is marked by the disappearance of *Globigerina digitata, Globigerinoides conglobata* and *Globorotalia barissanensis* and by the appearance of *Globorotalia menardii, Sphaeroidinella dehiscens* and, locally, *Palmerinella thalmanni*. The disappearance of benthonic species typical of the Tosagua and Viche shales is partly of regional significance but is also partly due to the complete elimination of the neritic facies in Ecuador at the end of the Oligocene, as in the cases of *Siphogenerina multicostata* and *Uvigerina rustica*. Regionally these changes in pelagic Foraminifera correspond to the Oligocene-Miocene boundary in Venezuela, Trinidad, Colombia and possibly Cuba (see note above). True *G. menardii* has been recorded only from the Miocene in Jamaica, Haiti, Florida and Panama. In northern Ecuador the base of the Miocene is often marked on the surface by an assemblage with floods of *Siphogenerina transversa*, but this belongs to a specialized facies intermediate between foreset and topset beds and, like them, varies in age according to locality.

There is a general faunal similarity between the Onzole and Charapotó of Ecuador and the Saucesian-Relizian of California. Species of *Bolivina* are numerous and might prove applicable to detailed correlation between the Californian and Ecuadorean Miocene. The abundance of *Valvulineria* spp. and *Bolivina* spp. is reminiscent of the Recent faunas dredged off the west coast of America (Cushman 1927) and supports the conclusion that a cool-water province was a long-standing feature of the West Coast Tertiary marine environment. This may account for faunal differences between the western fringe and the eastern part of the Caribbean region.

In sublittoral facies the younger Miocene Borbón silt of Ecuador contains an impoverished assemblage of Onzole type, with few new species. One of these is *Bolivina* cf. *hughesi*, a marker for the upper Mohnian in California (Kleinpell 1938, pp. 138, 273). C. D. Redmond (private communication) drew attention to this species at a similar level in southwestern Colombia. Of more general interest is the neritic younger Miocene, which in Ecuador carries a fauna

reminiscent in a general way of the Viche and Tosagua, though differing considerably in species. The Bowden and Buff Bay (Manchioneal) beds of Jamaica are closely similar, and it is especially significant that multicamerate *Globorotalia menardii* vars. only appear in the younger beds of Jamaica (see Cushman and Jarvis 1930, p. 367, pl. 4, fig. 8 and D. K. Palmer 1945, pp. 8, 9, 70). This is also true of Ecuador. The Port-au-Prince beds of Haiti are closely similar, but contain only the normal form of *G. menardii* (Coryell and Rivero 1940, p. 336). The Bowden and Port-au-Prince beds are usually considered late Middle Miocene, the Manchioneal as Upper Miocene. The Pliocene Charco Azul of Panama (Coryell and Mossman 1942) carries a similar fauna, *Pulleniatina obiquiloculata* and *Uvigerina peregrina parvula* being only two of several species typical of the young neritic Miocene in Ecuador. The importance of comparison of these late Miocene Antillean and Ecuadorean faunas lies in their bearing on the time of closure of the Central American land barrier. The pronounced similarity indicates that the barrier was not closed in late Miocene time, or else had not been closed long enough for evolutionary divergence of Pacific and Caribbean stocks.

*Bolivinita* cf. *quadrilatera* appears only in the youngest neritic Miocene of Ecuador and except for *B. angelina* from the Lower Pliocene of California there seem to be no other records at comparable levels in the Caribbean region. It is not established whether the absence of the genus in the West Indian faunas is of age-significance or whether this is yet another sign of a cool facies confined to the west coast of America. Molluscs closely associated include plentiful *Lucinoma*, according to a private communication from A. A. Olsson, who also states that this is a cold water genus.

## MOLLUSCAN FAUNAS

The time terms used in the foregoing portions of this paper are part of what may be called the foraminiferal time-scale. Vaughan and others have given a concrete backing to this biochronologic framework with their studies of the evolutionary development of the larger Foraminifera. In a more empirical manner Hedberg, Kleinpell and many others have provided the base for an equivalent zonation based on smaller Foraminifera. The main purpose of the present paper has been to show that the Tertiary microfaunas of Ecuador conform with the accepted succession of foraminiferal stages. Parallel studies of molluscs have led to the recognition of a succession of key species, genera and assemblages applicable to the definition of different time-levels within the Tertiary. In Ecuador A. A. Olsson has made extensive studies of the molluscan faunas and within close limits his statements on local and regional correlation have matched the conclusions based on Foraminifera.

There is some divergence of opinion regarding the application of the standard European time terminology of the molluscan specialists and by the Foraminifera specialists. This dual chronology has been discussed elsewhere (e.g. in Schenck and Childs 1942, pp. 54–63; Weaver *et al.*, 1944) and has arisen as a natural result of the difficulties of direct correlation between the European and American Tertiary. In general the molluscan faunas tend to be determined as slightly younger than synchronous foraminiferal assemblages, but no confusion need arise provided the duality and non-absolute nature of the time-terminology be recognized.

As mentioned above, equivalent molluscan and foraminiferal assemblages have been given closely similar age assessments in Ecuador. There is agreement, for instance, that the Playa Rica is early Oligocene, the uppermost Angostura Lower Miocene and the youngest neritic Borbón (at Punta Gorda) late Miocene. There is, however, one instance in which agreement has not been reached and the discrepancy needs to be clarified because the same molluscan fauna is the sole criterion of age of certain formations in Colombia and Venezuela. This is the assemblage first described from the Mancora of northern Peru and the equivalent Zapotal of Ecuador (Olsson 1931). More recently it has been referred to as the *Hannatoma*-fauna in the Barco Concession of Colombia (Notestein *et al.* 1944, pp. 1199–1201). Olsson has consistently claimed a

Middle Oligocene age for these molluscs, but in Ecuador they occur below shales which fall in the Upper Eocene foraminiferal stage. Put very briefly the cogent points raised in the contradictory age-assessments are:

Mollusca: In Peru the evolutionary development of *Venericardia planicosta* reached completion in the Saman. This is taken to mark the end of the Eocene epoch, hence the overlying Chira is Lower Oligocene (Olsson 1928, pp. 12–14; 1931, pp. 4, 6). The Mancora overlies the Chira: The Mancora-Zapotal fauna as first described was almost entirely new, but significance was attached to the presence of *Ampullinopsis spenceri*, previously recorded from the Antigua formation, and a Middle Oligocene age was claimed (Olsson 1931, p. 26). Unpublished notes by Olsson and J. G. Marks have since established that the species is nearer the Vicksburg *A. mississippiensis*.

Foraminifera: The Zapotal group is a complex of shallow marine to brackish sediments. In subsurface, sands correlative with the type Zapotal sands and carrying the same Mancora-Zapotal molluscs are consistently present below shales with a rich foraminiferal fauna including such species as *Bulimina, jacksonensis, Globigerina danvillensis, Hastigerinella eocenica* and, in one instance, *Hantkenina alabamensis*. This is direct evidence of an Upper Eocene age by accepted foraminiferal biochronology. Higher in the section, well above the youngest Mancora-Zapotal molluscs, the Eocene-Oligocene boundary is marked as usual by the evolutionary change from *Bulimina jacksonensis* to *B. sculptilis*. Stone (1946) mentioned *Hantkenina* in the Chira of Peru, as evidence that it is Upper Eocene in the foraminiferal time-scale.

These are the most direct lines of argument, but there is indirect evidence which can be used to support either conclusion. For instance the sandstones at Ancon Point, Punta Mambra and elsewhere in the south are broadly correlated with the Zapotal on field evidence. They contain a molluscan suite of *Thyasira, Acila, Pleurophopsis*, etc. which can be considered Oligocene by reference to the Californian succession; but on the other hand shales interbedded with and overlying these sands contain *Hastigerinella eocenica* and Radiolaria locally diagnostic of the foraminiferal Eocene. In the subsurface at Manta a rich *Hantkenina*-fauna appears at a much higher level than the local occurrence of the molluscs cited. Near Valdivia J. G. Marks has an unpublished record of *Tubulostium* sp. at a higher level than these molluscs.

To the extent that the units of the European time-scale are terms of convenience when applied in South America, the question of which age-determination is correct cannot be resolved; but it is essential for clarity that the terminology used in a regional correlation should be uniformly based on either the molluscan or the foraminiferal time-scale. In the excellent papers by Notestein *et al.* (1944) on the Barco Concession and by Sutton (1946) on the Maracaibo Basin, the upper Carbonera and the La Victoria formations are identified as Middle Oligocene on the strength of their contained *Hannatoma*-faunas. By field relations the almost barren Bebedero, Icotea and El Fausto formations are similarly referred. On the other hand the Pauji is assigned to the Upper Eocene by Sutton, on account of its foraminiferal fauna. The Pauji Foraminifera as described by Nuttall (1935) show it to be an exact equivalent of the Zapallo of northern Ecuador and other units mentioned earlier as characteristic of the neritic facies of the Upper Eocene foraminiferal stage. The shales overlying the Zapotal molluscan sandstones belong to a shallower marine facies but are unequivocably placed also in the Upper Eocene foraminiferal stage. It is therefore anomalous to refer the upper Carbonera, etc. and the Pauji to considerably different zones. Some elasticity may be allowed because the *Hannatoma*-fauna is largely facies-controlled, indicative of semi-brackish conditions, and some of its components may be long-ranging, but within close limits the Upper Eocene foraminiferal stage as generally accepted should be treated as synonymous with the Middle Oligocene of the Peruvian molluscan time-scale.

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JOURNAL OF PALEONTOLOGY, VOL. 22, NO. 2, PP. 152–174, PLS. 27–31, 1 TEXT FIG., MARCH 1948

# FORAMINIFERA FROM THE PORTER SHALE (LINCOLN FORMATION), GRAYS HARBOR COUNTY, WASHINGTON

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ABSTRACT—From an exposure of the Porter shale near Porter, in southwestern Washington, 51 species and varieties of Foraminifera have been collected. The assemblage suggests that the containing beds were deposited in a warm to temperate, shallow, off-shore, marine environment. The fauna strongly indicates an age not older than Upper Eocene and not younger than Middle Oligocene. However, the Foraminifera, taken by themselves, seem to favor an Upper Eocene age rather than the most frequently accepted Middle Oligocene, and therefore all or part of the Porter may be as old as Upper Eocene.

## INTRODUCTION

UNTIL recently the age-determination and correlation of marine Tertiary sediments in Washington State have been based largely on mollusks and only in the last few years have the associated Foraminifera been studied. Hanna and Hanna (1924) published one of the first contributions which dealt with Foraminifera from the Cowlitz formation. This publication was followed by a preliminary analysis of the type Lincoln fauna by Frizzell and Blackwelder (1933) in which a number of species of Foraminifera were listed and illustrated. In 1940, Cushman and Frizzell described and illustrated two new species of Foraminifera from the Lincoln formation of Washington. This work was followed by the description and illustration of a faunal assemblage from the type area of the Lincoln formation by Cushman and Frizzell (1943). Beck's study (1943) of Foraminifera from the Cowlitz formation is the most recent published contribution to the micropaleontology of this area. Cushman and Schenck (1928), Bandy (1944), and Detling (1946) have published contributions dealing with Tertiary Foraminifera from the adjacent area of western Oregon.

In the present paper additional Foraminifera from the Porter shale of the Lincoln formation are described and their significance discussed. All material studied has been collected by Dr. R. L. Lupher from new road cuts that extend some 4,000 feet southeast of Porter Creek along the east side of State Highway 9 between Aberdeen and Centralia in Grays Harbor County, Washington (E½ sec. 28, T. 17 N., R. 5 W., Ford quadrangle, U. S. Army Engineers).

## COLLECTING ZONES

The stratigraphic order of zones from which samples were collected are as follows:

Zone 5.—140 feet stratigraphically above lowest exposed bed.

Zone 4.—115 feet stratigraphically above lowest exposed bed.

Zone 3.—65 feet stratigraphically above lowest exposed bed.

Zone 2.—15 feet stratigraphically above lowest exposed bed.

Zone 1.—lowest exposed bed in the section; south end of the exposure.

## THE LINCOLN FORMATION

Weaver (1912, p. 15) originally applied the name Lincoln formation to marine beds in southern Thurston County, Washington, which were best exposed on Lincoln Creek near the boundary between Lewis and Thurston counties. Since then, the type section has been expanded and now includes a number of outcrops exposed in the banks of the Chehalis River between Centralia and Porter, Washington, and in the hills southwest of these towns (Weaver, 1944, p. 592). According to Weaver these beds are generally composed of brownish-gray medium-grained, shaly, and tuffaceous sandstone,

and locally attain a thickness of as much as 6,000 feet. The Lincoln formation is stated to be at least in part overlain by Blakeley beds (Etherington, 1931, p. 46; Weaver, 1937, p. 110) which are generally considered to be Upper Oligocene in age. Weaver (1944, p. 593) stated that the Astoria formation also unconformably overlies the Lincoln formation in southwestern Washington. According to Frizzell and Blackwelder (1933, p. 54), the Lincoln formation overlies the sedimentary Cowlitz formation and also Eocene volcanic rocks. Weaver (1944, p. 592) noted that in southwestern Washington the Lincoln formation overlies the Keasey formation. The Keasey formation is regarded as younger than the Cowlitz and older than the Lincoln. Various authors consider the Keasey to be either Upper Eocene or Lower Oligocene in age.

*The Porter Shale.*—Strata referred to as the Porter shale, from which the samples for the present study have been collected, were originally correlated with the lower portion of the Blakely formation (Weaver, 1912, p. 15). At the same time, many species of mollusks were found to be common to both the Porter shale and Lincoln exposures. Later, Weaver (1937, p. 110) included the Porter shale in the Lincoln formation and considered it as representing the middle part of the Lincoln formation.

It is therefore the general opinion of most authors that the Porter shale, as part of the Lincoln formation, is younger than the Keasey beds (Upper Eocene or Lower Oligocene) and older than the Blakeley formation (Upper Oligocene?).

## LITHOLOGY AND FOSSILS

All samples are light gray tuffaceous siltstone composed chiefly of very finely divided, angular, light colored material which, for the most part, is probably volcanic glass. Occasionally larger grains of quartz and both biotite and muscovite may be seen. Various amounts of pyrite are present and at least partially account for the different degrees of induration displayed in the samples.

Numerous fossil remains of various organisms are present in the samples and are, as a rule, in an excellent state of preservation. Besides an abundant assemblage of Foraminifera, there are ostracodes, sponge spicules, crustacean remains, fish teeth, microscopic mollusks, and fragments of larger mollusks.

## COMPOSITION OF FAUNA

The known Porter foraminiferal fauna consists of 50 species belonging in 31 genera of 14 families. One species, *Quinqueloculina imperalis* Hanna and Hanna, has been subdivided and a new variety established, making a total of 51 forms. Twenty-nine forms have been identified as species or varieties previously described; six have been listed as comparing closely with some previously described species; nine have been listed as new species or varieties; and seven forms have not been specifically classified as the available material is either insufficient or not well enough preserved to permit a definite identification.

As can be seen from figure 1, the genus *Robulus* comprises approximately 22 per cent of the total specimens. *Quinqueloculina*, *Gaudryina*, and *Cibicides* together make up approximately 32 per cent, *Epistomina*, *Pseudoglandulina*, and *Gyroidina* total approximately 22 per cent, and *Dentalina*, *Allomorphina*, *Vaginulinopsis*, *Planularia*, *Plectofrondicularia*, and *Karreriella* constitute approximately 12 per cent of the total specimens. These 13 genera comprise approximately 88 per cent of the total specimens in the fauna and are sufficiently abundant to be indicative of their natural environment.

## ENVIRONMENTAL CONDITIONS

Conclusions of various authors regarding the environmental conditions of the Lincoln formation have been summarized by Cushman and Frizzell (1943, p. 83) as tropical or subtropical with a depth variously estimated from shoreline to 200 fathoms. Frizzell and Blackwelder (1932, p. 60), as pointed out by Cushman and Frizzell, consider the mollusks of the type Lincoln sediments to indicate temperate marine water some 50 fathoms deep. The foraminiferal assemblage described by Cushman and Frizzell from the type area of the Lincoln formation is believed by them to indicate environmental conditions similar to those suggested by Frizzell and Blackwelder.

The foraminiferal fauna from the Porter shale of the Lincoln formation gives some indication as to the depositional environment. Conclusions are based on data published by Galloway in 1933 regarding ecological conditions of many genera which are identical with or very closely related to most of those of the Porter fauna:

28 genera (47 species) recorded from shallow water
19 genera (26 species) recorded from deep water
11 genera (23 species) restricted to shallow water
2 genera (2 species) restricted to deep water
17 genera (23 species) have a wide bathymetric range.

These data suggest that the Porter sediments were laid down in a fairly shallow sea. This conclusion is further substantiated by the following statistics regarding the depth at which only the commonly occurring Porter genera have been recorded:

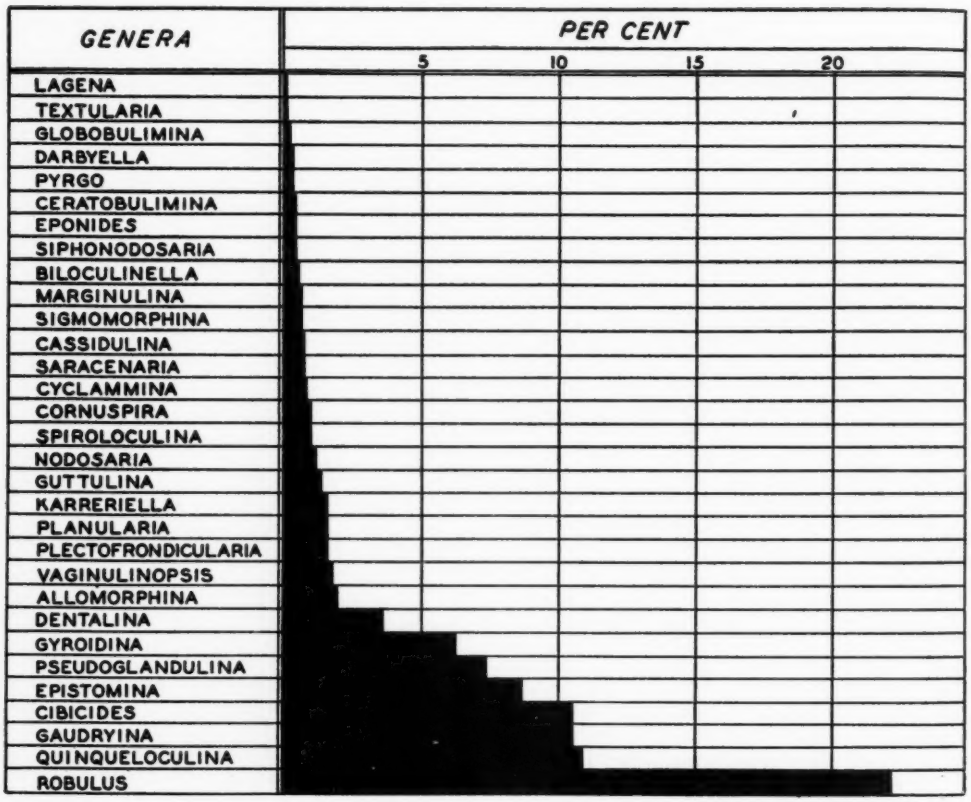



FIG. 1—Bar diagram showing relative abundance of the various genera of Foraminifera in the Porter shale.

6 genera (14 species) restricted to shallow water
1 genus (1 species) usually occurs in fairly deep water
6 genera (13 species) have a wide bathymetric range.

Furthermore, the nature of the sediments and other associated fossil remains confirm the belief that the Porter shale is a fairly shallow water marine deposit. The presence of crustacean remains together with thick shelled molluscan tests suggests that the

depth was not great. However, the absence of abundant carbonaceous material and worn fragmental molluscan tests strongly suggests that the deposit was not littoral.

With respect to temperature conditions during deposition, the following statistics show the occurrence of all Porter genera listed by Galloway:

16 genera (32 species) recorded from warm water
13 genera (20 species) recorded from cold water
6 genera (15 species) restricted to warm water
3 genera (3 species) usually occur in cold water
10 genera (17 species) associated with both cold and warm water.

The following information is based on seven abundantly occurring Porter genera on which Galloway has recorded information regarding temperature conditions:

3 genera (11 species) restricted to warm water
0 genus restricted to cold water
4 genera (11 species) associated with both cold and warm water.

From these figures it is apparent that the fauna favored a temperate to warm environment. There are many genera which occur in both warm and cold environments and could very well have been deposited in a warm or temperate sea. However, in any case there are substantially more forms present which definitely favor a warm environment rather than cold conditions.

Thus, the evidence set forth in this study regarding environment of deposition of the Porter shale suggests that deposition took place in a warm to temperate, shallow, off-shore, marine environment.

## AGE AND CORRELATION

The Porter foraminiferal fauna displays a very close relationship to the fauna described and illustrated by Cushman and Frizzell (1943) from the type area of the Lincoln formation in Lewis County, Washington. There are 17 genera and 23 species listed from the type area which occur in the Porter shale. Practically all forms listed from the type area of the Lincoln formation show a close relationship to species of the Porter fauna. Twelve species are common to both the Lincoln and Porter faunas. Of these 12 species, *Quinqueloculina imperalis* Hanna and Hanna and *Gyroidina orbicularis planata* Cushman occur abundantly in both faunas.

A Cowlitz fauna, described by Beck (1943), also bears a close resemblance to the Porter foraminiferal fauna. There are 21 genera and 10 species common to both faunas. *Quinqueloculina imperalis* Hanna and Hanna occurs abundantly in both assemblages.

Cushman and Simonson (1944) described and illustrated a foraminiferal fauna from the Tumey formation of California which contains over half the genera of the Porter fauna. Five species are common to both faunas and at least twenty Tumey species are closely related to species of the Porter fauna.

A foraminiferal assemblage from the Alazan shale of the Tampico Embayment, Mexico (Nuttall, 1932) appears somewhat similar to the Porter fauna. There are 10 genera common to both groups and at least 15 Alazan species are very closely related to species of the Porter fauna. Five of these species are regarded as identical. These general faunal comparisons suggest an Eocene or Oligocene age for the Porter beds.

The extreme abundance of *Robulus* in the Porter fauna (see figure 1) is significant since this genus is found most abundantly in the Cretaceous and Lower Tertiary. Furthermore, the only Porter species which occur in formations younger than middle Oligocene are those which have a wide stratigraphic range (see table 1). Thus, it would seem that an age not younger than Oligocene is suggested.

An analysis of the general stratigraphic range of previously recorded individual species of the Porter fauna (see table 1) reveals that most of the species occur in the Upper Eocene, Lower Oligocene, and Middle Oligocene. There are 26 species recorded from the Upper Eocene, 19 from the Lower Oligocene, and 15 (excluding species recorded from the type area of the Lincoln formation) from the Middle Oligocene. These figures suggest an Upper Eocene age for the Porter shale. It can also be seen from table 1 that there are five species which are considered to be restricted to the Upper

TABLE 1.—Stratigraphic distribution of Porter Foraminifera (including species which closely compare with Porter forms and excluding those known from only the Porter shale)

KEY

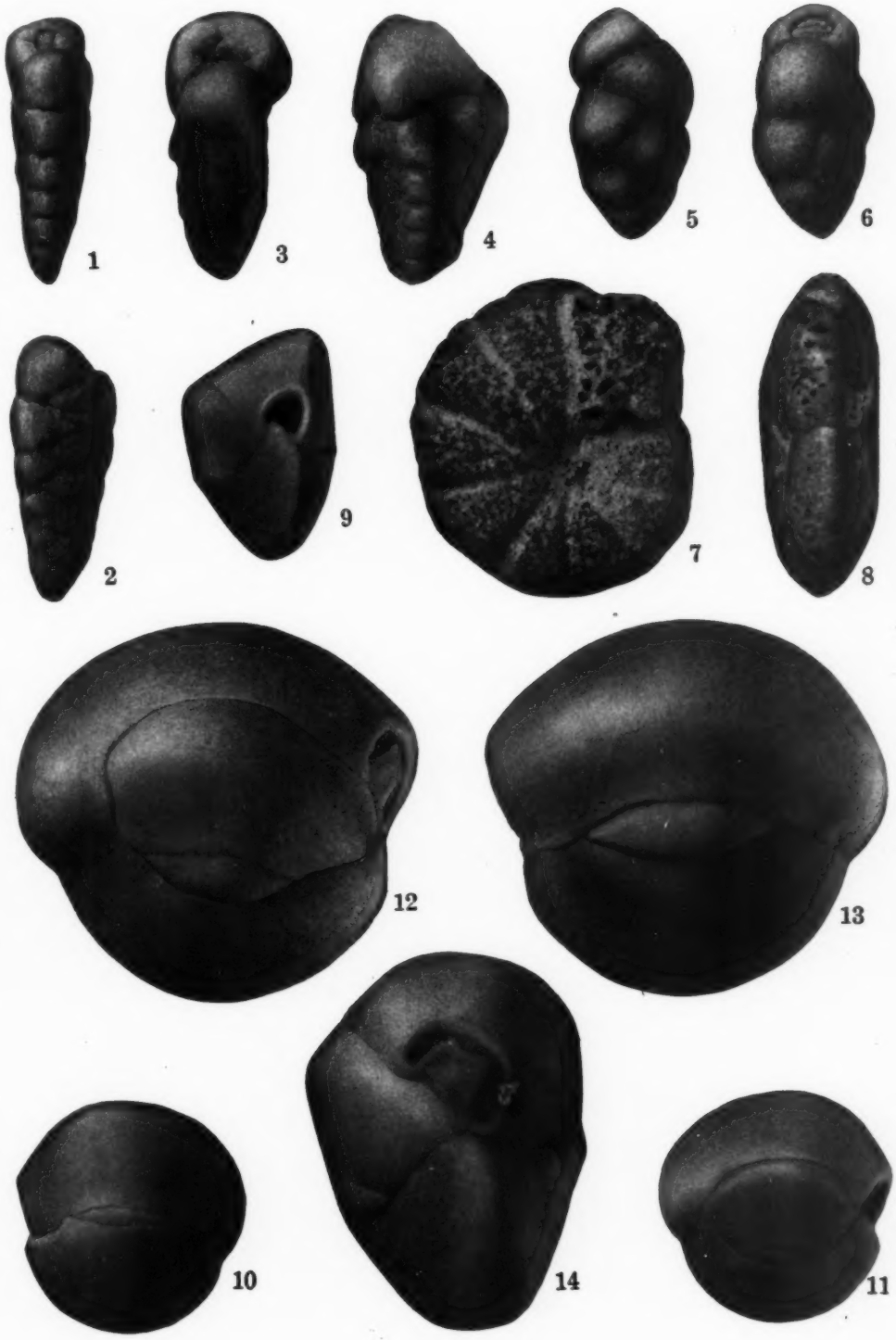
l—Lincoln formation only
p—Pacific Northwest in one sub-epoch only
r—Restricted to one sub-epoch but not the Pacific Northwest
w—More than one region and sub-epoch

| SPECIES \ AGE | Lower Eocene | Middle Eocene | Upper Eocene | Lower Oligocene | Middle Oligocene | Upper Oligocene | Lower Miocene | Middle Miocene | Upper Miocene | Pliocene | Pleistocene | Recent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Cyclammina pacifica* | | | w | w | | | | | | | | |
| *Textularia adalta* | | | r | | | | | | | | | |
| *Gaudryina alazanensis* | | | | r | | | | | | | | |
| *Quinqueloculina imperalis* | | | w | | l | | | | | | | |
| *Spiroloculina texana* | | | | | r | | | | | | | |
| *Biloculinella cowlitzensis* | | | p | | | | | | | | | |
| *Cornuspira byramensis* | w | | w | | w | | | | | | | |
| *Robulus budensis* | | | | r | | | | | | | | |
| *welchi* | | | w | w | w | | | | | | | |
| *weaveri* | | | p | | | | | | | | | |
| *gutticostatus cocoaensis* | | | r | | | | | | | | | |
| *limbosus hockleyensis* | | | w | w | w | | | | | | | |
| *texanus* | | | w | w | w | | | | | | | |
| *Planularia markleyana* | | | w | w | | | | | | | | |
| *Marginulina alazanensis* | | | w | w | | | | | | | | |
| *Vaginulinopsis saundersi* | | | w | w | | | | | | | | |
| *Dentalina vagina* | w | w | w | | | | | | | | | |
| *communis* | w | w | w | w | w | w | w | w | w | w | w | w |
| *adolphina* | | | w | w | w | w | w | w | w | | | |
| *dusenburyi* | | | p | | | | | | | | | |
| *Nodosaria grandis* | | | | | r | | | | | | | |
| *Pseudoglandulina inflata* | | | | | r | | | | | | | |
| *Saracenaria schencki* | | | | w | w | w | w | w | | | | |
| *Guttulina irregularis* | w | w | w | w | w | w | w | w | w | w | w | w |
| *hantkeni* | w | w | w | | | | | | | | | |
| *frankei* | | | | w | w | | | | | | | |
| *Sigmomorphina schencki* | | | w | w | | | | | | | | |
| *Plectofrondicularia packardi multilineata* | | | w | w | w | | | | | | | |
| *Globobulimina pacifica* | | | w | w | w | w | | w | | w | w | w |
| *Gyroidina orbicularis planata* | | w | w | | l | | | | | | | |
| *Eponides kleinpelli* | | | | | l | | | | | | | |
| *Epistomina eocenica* | | w | w | w | w | | | | | | | |
| *Ceratobulimina washburnei* | | | w | w | l | | | | | | | |
| *Cassidulina galvinensis* | | | | | l | | | | | | | |
| *Allomorphina macrostomata* | | w | w | | | | | | | | | |

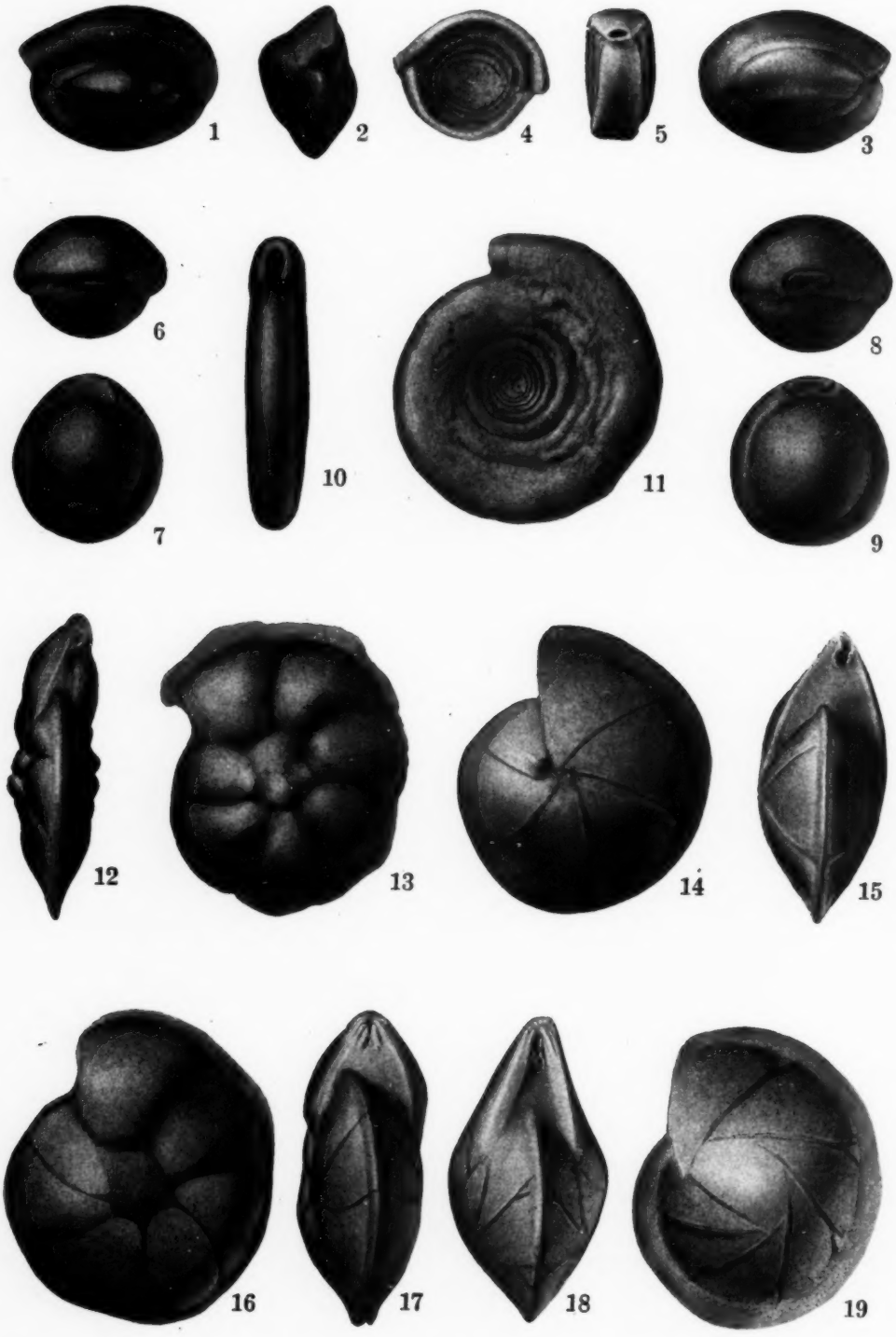
EXPLANATION OF PLATE 27

All specimens from the Porter shale, Grays Harbor County, Washington.

FIGS. *1, 2*—*Textularia* cf. *T. adalta* Cushman, ×35. (p. 158)
*3, 4*—*Gaudryina alazanensis* Cushman, ×35. (p. 158)
*5, 6*—*Karreriella washingtonensis* Rau, n. sp., Holotype, ×35. (p. 158)
*7, 8*—*Cyclammina pacifica* Beck, ×35. (p. 157)
*9–11*—*Quinqueloculina imperalis porterensis* Rau, n. var., Holotype, ×35. (p. 159)
*12–14*—*Quinqueloculina imperalis* Hanna and Hanna, ×35. (p. 159)




Rau, Early Tertiary Foraminifera




Rau, Early Tertiary Foraminifera

Eocene, two to the Lower Oligocene, and three to the Middle Oligocene. Thus, approximately 19 per cent of the species recorded from the Upper Eocene, 11 per cent of the species recorded from the Lower Oligocene, and 20 per cent of the species recorded from the Middle Oligocene have been previously regarded as restricted to these respective stratigraphic zones. These comparisons suggest either an Upper Eocene or Middle Oligocene age.

As pointed out previously, the Tertiary foraminiferal faunas of the Pacific Northwest are still largely unstudied. Therefore it is possible that many species which have been previously recorded from only one formation in this area may later be found to have a greater stratigraphic range. Only two of the five species previously regarded as restricted to the Upper Eocene have been recorded from areas other than the Pacific Northwest. However, both of the two regarded as restricted to the Lower Oligocene, and all of the three regarded as restricted to the Middle Oligocene are known to occur in areas other than the Pacific Northwest. This information may be considered as supporting evidence indicative of a Middle Oligocene age but it is not particularly significant.

Thus, in conclusion it can be said that the Porter foraminiferal fauna strongly indicates an Upper Eocene to Middle Oligocene age. The numerical preponderance of foraminiferal species which occur in the Upper Eocene and the lack of strong foraminiferal evidence to support the more specific and most frequently accepted Middle Oligocene age, suggests that a Middle Oligocene age for the Porter shale should be questioned and that it is possible that all or part of the Porter shale may be as old as Upper Eocene.

ACKNOWLEDGMENTS

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## SYSTEMATIC DESCRIPTIONS

### Family LITUOLIDAE
### Genus CYCLAMMINA Brady, 1876
### CYCLAMMINA PACIFICA Beck
### Plate 27, figures 7, 8

*Cyclammina pacifica* BECK, 1943, Jour. Paleontology, vol. 17, p. 591, pl. 98, figs. 2, 3.—DETLING, 1946, Jour. Paleontology, vol. 20, p. 352, pl. 46, fig. 1.

*Dimensions.*—Minimum and maximum length, 1.06–1.70 mm.; breadth, 0.97–1.91 mm.; thickness, 0.47–0.89 mm.

*Remarks.*—Several fairly well preserved and numerous fragmentary specimens of this species occur in the shale samples of this study. They vary considerably in shape in that some are almost circular whereas others are somewhat elongate. The elongate forms may be the result of distortion during preservation, but it is rather unlikely as the long axis in all cases is approximately parallel to the apertural face.

In the original description of this species Beck noted that the sutures are lighter colored than the rest of the test. This feature is well displayed in the present specimens. The color distinction is caused by grains of some dark mineral which occur in the walls of the chambers but are never present in the

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EXPLANATION OF PLATE 28

All specimens from the Porter shale, Grays Harbor County, Washington.

FIGS. *1, 2, 3—Quinqueloculina weaveri* Rau, n. sp., Holotype, ×35. (p. 159)
*4, 5—Spiroloculina texana* Cushman and Ellisor, ×35 (p. 160)
*6, 7—Biloculinella cowlitzensis* Beck, ×35. (p. 160)
*8, 9—Pyrgo lupheri* Rau, n. sp., Holotype, ×35. (p. 160)
*10, 11—Cornuspira byramensis* Cushman, ×25. (p. 160)
*12, 13—Robulus budensis* Hantken, ×25 (p. 161)
*14, 15—Robulus lincolnensis* Rau, n. sp., Holotype, ×25. (p. 161)
*16, 17—Robulus* cf. *R. welchi* Church, ×25. (p. 161)
*18, 19—Robulus weaveri* Beck, ×25. (p. 162)

sutural areas. Usually this dark mineral is dispersed throughout the whole test. However, in some specimens the first few chambers, or in some, all of the chambers lack dark mineral grains. All specimens are somewhat umbilicate. The aperture is not distinct, but appears to be a long narrow slit normal to and extending beyond each side of the periphery.

*Occurrence.*—Zones 1 to 3 in Porter shale near Porter, Washington. Conspecific specimens have been reported previously from the Cowlitz formation of Washington and the Coaledo and Bastendorf formations of Oregon.

*Hypotypes.*—State Univ. of Iowa, 9426 (figured specimen), 9427 (unfigured specimens).

Family TEXTULARIIDAE
Genus TEXTULARIA Defrance, 1824
TEXTULARIA cf. T. ADALTA Cushman
Plate 27, figures 1, 2

?*Textularia adalta* CUSHMAN, 1926, Cushman Lab. Foram. Research Contr., vol. 2, pt. 2, p. 29, pl. 4, figs. 2a, b.—ELLISOR, 1933, Am. Assoc. Petroleum Geologists Bull., vol. 17, no. 11, pl. 6, fig. 2.—CUSHMAN, 1935, U. S. Geol. Survey Prof. Paper 181, p. 8, pl. 1, figs. 11, 12.

*Description.*—Test small, somewhat compressed, quite narrow, tapering from last formed pair of chambers to a subacute angle at the initial end, broadly elliptical when viewed from the top; chambers numerous, last 9 or 10 considerably overlapped, slightly inflated and making up at least three fourths of test, early chambers indistinguishable; sutures distinct between the last 9 or 10 chambers, straight and almost horizontal where chambers do not overlap, indistinct between early chambers; walls finely arenaceous with a large amount of cement; aperture indistinct, probably an arched opening on the inner margin of the last formed chamber.

Length, 1.10 mm.; breadth, 0.46 mm.; thickness, 0.36 mm.

*Remarks.*—A single arenaceous specimen which displays all the characteristics of the genus *Textularia* appears very similar to the published figure of *Textularia adalta* Cushman (1926, p. 29, pl. 4, fig. 2). Until more material is available, it will perhaps be best to designate this form as *Textularia* cf. *T. adalta*.

*Occurrence.*—Zone 3 in Porter shale near Porter, Washington. *T. adalta* occurs in the Jackson formation of Alabama and Texas.

*Figured specimen.*—State Univ. Iowa, 9428.

Family VERNEUILINIDAE
Genus GAUDRYINA d'Orbigny, 1839
GAUDRYINA ALAZANENSIS Cushman
Plate 27, figures 3, 4

*Gaudryina alazanensis* CUSHMAN, 1936, Cushman Lab. Foram. Research Spec. Publ. no. 6, p. 14, pl. 2, fig. 17; 1937, Cushman Lab. Foram. Research Spec. Publ. no. 7, p. 91, pl. 13, fig. 9.

*Dimensions.*—Minimum and maximum length, 0.55–1.70 mm.; breadth, 0.42–0.68 mm.; thickness, 0.34–0.63 mm.

*Remarks.*—This form is quite common in the Porter material. It conforms well with the published description and illustration of *Gaudryina alazanensis* from the Lower Oligocene of Mexico. The present specimens vary slightly from Cushman's form only in that the arenaceous walls are composed of finer sand grains and perhaps contain more cement. Several stages of development are shown in these specimens. Some represent only the early triangular, triserial stage, while others are more fully developed with an added biserial stage represented by one or two pairs of inflated chambers.

*Occurrence.*—Zones 1 to 5 in Porter shale near Porter, Washington. The type specimen came from the Lower Oligocene near Rio Tuxpam, Vera Cruz, Mexico.

*Hypotypes.*—State Univ. Iowa, 9429 (figured specimen), 9430 (unfigured specimens).

Family VALVULINIDAE
Genus KARRERIELLA Cushman, 1933
KARRERIELLA WASHINGTONENSIS Rau, n. sp.
Plate 27, figures 5, 6

*Description.*—Test elongate, tapering rapidly in a convex manner from the acute initial end, approaching greatest breadth early in development; chamber arrangement indistinct in early stage, later triserial, finally biserial and arranged in a somewhat twisted manner, triserial and biserial stages inflated; sutures indistinct in initial stage, distinct and depressed in later development; walls finely arenaceous; aperture a narrow elliptical opening, slightly arched, distinctly

necked and protruding at an acute angle to the axis of test elongation from a sunken area in the face of the last formed chamber.

Minimum and maximum length, 0.63–1.00 mm; breadth, 0.47–0.53 mm.

*Remarks.*—The aperture of this species is quite similar to that of *Karreriella subcylindrica* (Nuttall) var. *caribaea* Acosta, listed in the Catalogue of Foraminifera by Ellis and Messina. But the test differs in that the length is considerably less in relation to its breadth, the chambers display less inflation, and the sutures are not as well defined.

*Occurrence.*—Zone 2 in Porter shale near Porter, Washington.

*Holotype.*—State Univ. Iowa, 9431.

Family MILIOLIDAE

Genus QUINQUELOCULINA d'Orbigny, 1826

QUINQUELOCULINA IMPERALIS Hanna and Hanna

Plate 27, figures 12, 13, 14

*Quinqueloculina imperalis* HANNA and HANNA, 1924, Washington Univ. (Seattle) Publ. in Geol., vol. 1, no. 4, p. 58, pl. 13, figs. 7, 8, 10.—BECK, 1943, Jour. Paleontology, vol. 17, p. 592, pl. 98, figs. 9, 10.

*Dimensions.*—Minimum and maximum length, 0.93–2.33 mm.; breadth, 0.76–2.29 mm.; thickness, 0.42–1.40 mm.

*Remarks.*—The present specimens of *Q. imperalis* are of two general sizes. The smaller ones, which are about half the size of the larger ones, are much more numerous. Thin sections of the two forms show that the small specimens have fewer chambers and a larger proloculum than the large specimens. The apertual dentition of *Q. imperalis* has been described as a heavy bifid tooth, a single pointed tooth and a simple tooth-like projecting plate (Beck, 1943, p. 592). All three types of dentitions are present in the Porter specimens. However, in all cases, the plate-like dentition is confined to the large specimens. The relative number of specimens, the number of chambers, the size of the proloculum and the shape of the apertural dentition of the large specimens compared with that of the smaller specimens suggests that the large ones probably represent the microspheric form whereas the smaller ones probably represent the megalospheric form of *Q. imperalis*.

*Occurrence.*—Zones 1 to 5 in Porter shale near Porter, Washington, and known previously from the Cowlitz and Lincoln (type locality) formations of Washington.

*Hypotypes.*—State Univ. Iowa, 9432 (figured specimen), 9433 (unfigured specimens).

QUINQUELOCULINA IMPERALIS PORTERENSIS Rau, n. var.

Plate 27, figures 9, 10, 11

*Dimensions.*—Minimum and maximum length, 0.63–0.93 mm.; breadth, 0.59–0.90 mm.; thickness, 0.30–0.66 mm.

*Remarks.*—A few specimens appear almost identical to the probable megalospheric form of *Q. imperalis* Hanna and Hanna, but vary in that the aperture has no dentition. The aperture is rounded at the top with the sides approaching parallelism and the floor flat with no sign of any protrusion.

*Occurrence.*—Zones 1, 2, and 4 in Porter shale near Porter, Washington.

*Holotype.*—State Univ. Iowa, 9434.

QUINQUELOCULINA WEAVERI Rau, n. sp.

Plate 28, figures 1, 2, 3

*Description.*—Test elongate, about three fourths as broad as long, slightly compressed, periphery broadly rounded, last formed chamber truncated with apertural face bent back forming an acute angle with the periphery, in cross section sides of test slightly concave, chambers fairly distinct, slightly depressed, last formed chamber strongly curved at end opposite aperture, sutures distinct, very slightly depressed; walls smooth, shiny; aperture circular with a flattened base at the terminus of the last formed chamber, no apparent dentition.

Minimum and maximum length, 0.60–0.81 mm.; breadth, 0.43–0.60 mm.; thickness, 0.36–0.40 mm.

*Remarks.*—This species resembles *Q. venusta*? Karrer figured by Cushman from the Miocene of the coastal plain of eastern United States (1918, p. 70, pl. 28, fig. 3, and pl. 29, fig. 2). It differs, however, in that the aperture is more nearly circular, apparently void of any tooth, and the chambers are less nearly angular. The form under consideration is also similar to *Q. minuta* Beck (1943, p. 593, pl. 99, figs. 5, 6, 7), but differs in that it is about twice as large, the ratio of length to breadth is smaller, the chambers are more strongly compressed, and the

angle between the apertural face and the periphery is smaller.

*Occurrence.*—Zones 1 to 4 in Porter shale near Porter, Washington.

*Holotype.*—State Univ. Iowa, 9435.

Genus SPIROLOCULINA d'Orbigny, 1826
SPIROLOCULINA TEXANA Cushman and Ellisor
Plate 28, figures 4, 5

*Spiroloculina texana* CUSHMAN and ELLISOR, 1944, Cushman Lab. Foram. Research Contr., vol. 20, pt. 2, p. 51, pl. 8, figs. 14, 15.

*Dimensions.*—Length, 0.66 mm.; breadth, 0.56 mm.; thickness, 0.26 mm.

*Remarks.*—A few specimens have a striking resemblance to the holotype of *S. texana* Cushman and Ellisor. The shape, size, number of chambers, and sutures all coincide well with the published description and illustrations of this species. However, the aperture varies in that it is elliptical with the long axis parallel to the thickness of the test and at the end of a very short, thin neck. The holotype is described as having a circular aperture with a thickened rim and a short, broad, simple tooth on the inner margin. Inasmuch as in every way, except the aperture, these specimens resemble the type of *S. texana*, they are referred to that species although they may represent a distinct variety.

*Occurrence.*—Zones 1 to 3 in Porter shale near Porter, Washington. Holotype described and illustrated from the Middle Oligocene in Brazoria County, Texas.

*Figured specimen.*—State Univ. Iowa, 9436.

Genus PYRGO Defrance, 1924
PYRGO LUPHERI Rau, n. sp.
Plate 28, figures 8, 9

*Description.*—Test small, slightly longer than broad, somewhat broader than thick, periphery broadly rounded; chambers distinct and inflated, last formed chamber considerably broader and longer than the adjacent one, last two chambers forming the complete exterior; sutures distinct, very slightly depressed; walls smooth, shiny; aperture elliptical with axis of elongation parallel to breadth of test, very slightly collared, with a bifid plate-like protrusion attached at the base by a narrow connection and practically filling the aperture.

Minimum and maximum length, 0.63–0.71 mm.; breadth, 0.59–0.66 mm.; thickness, 0.54–0.56 mm.

*Remarks.*—A few Porter specimens vary only slightly from *Biloculinella cowlitzensis* Beck in that the tooth is distinctly bifid instead of plate-like. Apparently a very close relationship exists between these two forms. The arrangement of the chambers and the shape of the test are identical in both forms. According to Cushman (1940, p. 171) the genus *Biloculinella* is distinguished from *Pyrgo* only by a broad, flat tooth in the aperture. Although these two forms are very similar, they are best referred to separate but closely related genera.

*Occurrence.*—Zone 3 in Porter shale near Porter, Washington.

*Holotype.*—State Univ. Iowa, 9438.

Genus BILOCULINELLA Wiesner, 1931
BILOCULINELLA COWLITZENSIS Beck
Plate 28, figures 6, 7

*Biloculinella cowlitzensis* BECK, 1943, Jour. Paleontology, vol. 17, p. 594, pl. 101, figs. 6, 7.

*Dimensions.*—Minimum and maximum length, 0.59–0.71 mm.; breadth, 0.55–0.62 mm.; thickness, 0.46–0.50 mm.

*Remarks.*—Several specimens are comparable in every respect to *B. cowlitzensis* Beck.

*Occurrence.*—Zones 1 to 4 in Porter shale near Porter, Washington. Type specimen from Cowlitz formation of Washington.

*Figured specimen.*—State Univ. Iowa, 9437.

Family OPHTHALMIDIIDAE
Genus CORNUSPIRA Schultze, 1854
CORNUSPIRA BYRAMENSIS Cushman
Plate 28, figures 10, 11

*Cornuspira byramensis* CUSHMAN, 1935, Cushman Lab. Foram. Research Contr., vol. 11, pt. 2, p. 27, pl. 4, figs. 4a, b.—CUSHMAN and GARRETT, 1939, Cushman Lab. Foram. Research Contr., vol. 15, pt. 4, p. 79, pl. 13, fig. 8.—CUSHMAN and FRIZZELL, 1943, Cushman Lab. Foram. Research Contr., vol. 19, pt. 4, p. 83, pl. 14, fig. 4.
*Cornuspira lewisensis* BECK, 1943, Jour. Paleontology, vol. 17, p. 594, pl. 101, figs. 4, 5.

*Dimensions.*—Minimum and maximum diameter 0.45–2.12 mm.; thickness, 0.05–0.34 mm.

*Remarks.*—A number of specimens are referable to *C. byramensis* Cushman. Some have a diameter more than four times that of the holotype, but others display a distinct size gradation to a diameter which is even less than that of the holotype. Beck described *C. lewisensis* from the Eocene of Washington as being distinct from *C. byramensis* in that it is more than twice as large. The extreme variation in size exhibited by the present specimens indicates that only one species is represented.

*Occurrence.*—Zones 1 to 4 in Porter shale near Porter, Washington, and known previously from the Byram marl of Mississippi, the Wilcox group of Alabama, and the Cowlitz and Lincoln (type locality) formations of Washington.

*Hypotypes.*—State Univ. Iowa, 9439 (figured specimen), 9440 (unfigured specimens).

Family LAGENIDAE
Genus ROBULUS Montfort, 1808
ROBULUS BUDENSIS (Hantken)
Plate 28, figures 12, 13

*Robulina budensis* HANTKEN, 1875, Magyr. kir földt int. évkön., vol. 4, p. 49, pl. 7, fig. 1.
*Cristellaria budensis*, NUTTALL, 1932, Jour. Paleontology, vol. 6, p. 9, pl. 1, fig. 5.
*Robulus budensis*, CUSHMAN, 1927, Jour. Paleontology, vol. 1, p. 151, pl. 23, fig. 11.—FRANKLIN, 1944, Jour. Paleontology, vol. 18, p. 309, pl. 45, fig. 11.

*Dimensions.*—Length, 1.67 mm.; breadth, 1.47 mm.; thickness, 0.56 mm.

*Remarks.*—Several specimens are referred to *R. budensis* (Hantken). They differ slightly from Hantken's form in that the sutures appear more strongly curved and deeply incised. Specimens from the Oligocene of Mexico and Venezuela which have been referred to *R. budensis* by Cushman and Franklin respectively, seem very similar to the specimens under consideration.

*Occurrence.*—Zone 3 in Porter shale near Porter, Washington, and known previously from the Carapita formation of Venezuela, the Alazan shale of the Tampico Embayment, Mexico, the Oligocene of Cuba, and several localities in Europe, all lower Oligocene.

*Figured specimen.*—State Univ. Iowa, 9441.

ROBULUS LINCOLNENSIS Rau, n. sp.
Plate 28, figures 14, 15

*Description.*—Test large, involute, somewhat compressed, periphery with distinct keel; chambers distinct, five in the adult whorl, not inflated, of uniform shape, increasing very gradually in size as added; sutures thin but distinct, straight or very slightly curved, early ones slightly elevated, later ones flush with the surface, somewhat translucent, joining at the inner end at a point with no umbo; walls thins, smooth; aperture radiate with a fairly large supplementary medial slit in a flat triangular apertural face.

Minimum and maximum diameter, 1.70–2.67 mm.; thickness, 0.72–1.31 mm.

*Remarks.*—This form is rare in the present Porter samples. It is characterized by few chambers, narrow but distinct sutures, and a flat, triangular apertural face. *Robulina nitidissina* Reuss from the Eocene of Germany, described and illustrated in Ellis and Messina's catalogue of Foraminifera, is the only form that has come to the writer's attention which appears similar to this species. *R. nitidissina* differs in that it has an umbo and the apertural face is convex.

*Occurrence.*—Zone 3 in Porter shale near Porter, Washington.

*Holotype.*—State Univ. Iowa, 9442.

ROBULUS cf. R. WELCHI Church
Plate 28, figures 16, 17

*?Robulus welchi* CHURCH, 1931, *Figured in* Mining in California, vol. 27, no. 2, p. 213, pl. C, figs. 13, 14; *Described in* 1943, Califonia Dept. Nat. Resources, Bull. 118, pt. 2, p. 182.—BECK, 1943, Jour. Paleontology, vol. 17, p. 596, pl. 102, figs. 4, 8.—CUSHMAN and SIMONSON, 1944, Jour Paleontology, vol. 18, p. 195, pl. 30, figs. 11.—DETLING, 1946, Jour. Paleontology, vol. 20, p. 353, pl. 48, fig. 2.

*Dimensions.*—Length, 1.77 mm.; breadth, 1.55 mm.; thickness, 0.70 mm.

*Remarks.*—One essentially perfect specimen has many characteristics of *Robulus welchi* Church. However, it differs from the holotype in that it is considerably larger, the sutures of the later chambers are strongly curved and the later chambers are added slightly to one side, thus modifying its bilateral symmetry. These differences may be sufficient to warrant the establishment of

a new species, but more material will be necessary to confirm a consistent distinction.

*Occurrence.*—Zone 3 in Porter shale near Porter, Washington. *R. welchi* is known from the Markley and Tejon formations of California, and Coaledo and Bastendorf formations of Oregon, and the Cowlitz formation of Washington.

*Figured specimen.*—State Univ. Iowa, 9443.

ROBULUS WEAVERI Beck
Plate 28, figures 18, 19

*Robulus weaveri* BECK, 1943, Jour. Paleontology, vol. 17, p. 595, pl. 103, figs. 3, 8.

*Dimensions.*—Minimum and maximum height, 1.27–2.33 mm.; breadth, 1.07–2.00 mm.; thickness, 0.42–0.89 mm.

*Remarks.*—Numerous specimens are best referred to *R. weaveri.* They are typically higher than broad and with an asymmetric apertural face. The early apertures can also be seen on a number of specimens. These fundamental features characterize *R. weaveri* and vary only slightly in the present specimens. However, the thickness and width of the keel and curvature of the sutures vary considerably. Although not mentioned in the description of the holotype, all the present specimens display sutures which approach the umbonal region tangentially.

*Occurrence.*—Zones 1 to 5 in Porter shale near Porter, Washington. Type specimen described and illustrated from the Cowlitz formation of Washington.

*Hypotypes.*—State Univ. Iowa, 9444 (figured specimen), 9445 (unfigured specimens).

ROBULUS GUTTICOSTATUS COCOAENSIS
(Cushman)
Plate 29, figures 9, 10

*Cristellaria gutticostata* (Gümbel) var. *cocoaensis* CUSHMAN, 1925, Cushman Lab. Foram. Research Contr., vol. 1, pt. 3, p. 67, pl. 10, fig. 11.
*Robulus gutticostatus* var. *cocoaensis* CUSHMAN, 1945, U. S. Geol. Survey Prof. Paper 181, p. 15, pl. 5, figs. 3, 4.

*Dimensions.*—Minimum and maximum length, 0.63–1.51 mm.; breadth, 0.47–1.11 mm.; thickness, 0.38–0.66 mm.

*Remarks.*—Very common in samples from zone 3 are specimens which have all the characteristics of *R. gutticostatus cocoaensis*, originally described from the Cocoa sand of Alabama. Some of the present specimens show a variation from the typical form in that they are ornamented at the sutures by a fine papillae-like structure rather than the typical beaded structure. A few small, immature specimens are entirely free of or have very little ornamentation but most of these specimens appear essentially identical to the type.

*Occurrence.*—Zone 3 in Porter shale near Porter, Washington, and known previously from the Jackson formation of Alabama, Louisiana, and Texas.

*Hypotypes.*—State Univ. Iowa, 9446 (figured specimen), 9447 (unfigured specimens).

ROBULUS LIMBOSUS HOCKLEYENSIS
(Cushman and Applin)
Plate 29, figures 11, 12

*Cristellaria limbosa* (Reuss) var. *hockleyensis* CUSHMAN and APPLIN, 1926, Am. Assoc. Petroleum Geologists Bull., vol. 10, no. 2, p. 171, pl. 8, figs. 3a, b, 4.
*Robulus limbosus* var. *hockleyensis* ELLISOR, 1938, Am. Assoc. Petroleum Geologists Bull., vol. 17, no. 11, pl. 1, figs. 11a, b.—CUSHMAN and DUSENBURY, 1934, Cushman Lab. Foram. Research Contr., vol. 10, pt. 3, p. 52, pl. 7, fig. 1.—CUSHMAN, 1935, U. S. Geol. Survey Prof. Paper 181, p. 16, pl. 4, figs. 15a, b; pl. 6, figs. 3a, b.—CUSHMAN, 1939, Cushman Lab. Foram. Research Contr., vol. 15, pt. 3, p. 53, pl. 9, fig. 21.—CUSHMAN and SIMONSON, 1944, Jour. Paleontology, vol. 18, p. 194, pl. 30, fig. 9.

*Dimensions.*—Minimum and maximum length, 1.06–1.74 mm.; breadth, 0.85–1.70 mm.; thickness, 0.55–0.85 mm.

*Remarks.*—A number of specimens which show a wide variation in form, are best referred to *R. limbosus hockleyensis.* The main variables are the size of the umbo and the thickness of the test.

*Occurrence.*—Zones 2, 3, and 5 in Porter shale near Porter, Washington, and known previously from the Jackson formation from North Carolina to Texas, Poway conglomerate of southern California, and the Tumey formation of central California.

*Hypotypes.*—State Univ. Iowa, 9448 (figured specimen), 9449 (unfigured specimens).

ROBULUS CHEHALISENSIS Rau, n. sp.
Plate 29, figures 14, 15

*Description.*—Test large, compressed,

strongly involute with a rather thin translucent keel; umbo small and indistinct; chambers numerous, 9 in the last formed whorl; sutures flush with the surface, curved, slightly limbate especially near the keel; walls smooth; aperture radiate, with a median slit on the apertural face.

Minimum and maximum diameter, 1.74–2.33 mm.; thickness, 0.74–0.79 mm.

*Remarks.*—These specimens are similar to a Lower Oligocene Mexican form referred to by Nuttall (1932, p. 10, pl. 1, fig. 8) as *Cristellaria kemperi* but differ in being much larger. The present specimens differ considerably from the holotype of *C. kemperi* Hanna (1923, p. 323, pl. 59, fig. 1) in that the sutures are not raised but are slightly limbate and flush with the surface. This Porter form is typified by its large, thin, discoidal test and its numerous chambers and is best considered a new species.

*Occurrence.*—Zone 3 in Porter shale near Porter, Washington.

*Types.*—State Univ. Iowa, 9450 (holotype), 9451 (paratypes).

ROBULUS TEXANUS (Cushman and Applin)
Plate 29, figures 16, 17

*Cristellaria articulata* Reuss, var. *texana* CUSHMAN and APPLIN, 1926, Am. Assoc. Petroleum Geologists Bull., vol. 10, no. 2, p. 170, pl. 8, figs. 1, 2.

*Robulus articulatus* var. *texanus* ELLISOR, 1933, Am. Assoc. Petroleum Geologist Bull., vol. 17, no. 11, p. 1336, pl. 2, fig. 3.—CUSHMAN and DUSENBURY, 1934, Cushman Lab. Foram. Research Contr., vol. 10, pt. 3, p. 53, pl. 7, figs. 2, 3.—CUSHMAN, 1935, U. S. Geol. Survey Prof. Paper 181, p. 16, pl. 4, figs. 16, 17.—CUSHMAN and FRIZZELL, 1943, Cushman Lab. Foram. Research Contr., vol. 19, pt. 4, p. 83, pl. 14, fig. 10.—CUSHMAN and SIMONSON, 1944, Jour. Paleontology, vol. 18, p. 194, pl. 30, fig. 7.

*Robulus texanus* BECK, 1943, Jour. Paleontology, vol. 17, p. 595, pl. 103, figs. 1, 2, 4, 5.

*Dimensions.*—Minimum and maximum diameter, 0.76–1.85 mm.; thickness, 0.42–1.80 mm.

*Remarks.*—Numerous well-preserved specimens of this species occur in the Porter material and are typified by distinct umbos together with raised adult chambers. As described by Beck, the sutures are distinct and usually flush with the surface, but in the present adult specimens the last formed sutures are not uncommonly slightly depressed.

This form was originally referred to as *Cristellaria articulata texana* by Cushman and Applin. Later, Ellisor and numerous other authors referred to this form as *R. articulatus texanus*. Recently, Beck studied this form, which he found in the Cowlitz formation of Washington, and concluded it is sufficiently different from *C. articulata* Reuss to be considered a new species. The writer agrees.

*Occurrence.*—Zones 3 and 4 in Porter shale near Porter, Washington, and known previously from the Jackson formation in Texas and South Carolina, Poway conglomerate and Tumey formation of California, and the Cowlitz and Lincoln (type locality) formations of Washington.

*Figured specimen.*—State Univ. Iowa, 9452.

Genus DARBYELLA Howe and Wallace, 1933
DARBYELLA? sp.
Plate 29, figures 18, 19

*Description.*—Test large, involute, biconvex with one side more strongly convex than the other, periphery irregular, subcircular, with broad, rather thick keel, umbo present in some, absent in others; chambers, 5 or 6 in last whorl, added planispirally in early whorls; later chambers added on one side of early plane of coiling; sutures limbate, slightly depressed, curved; walls fairly smooth; aperture large, radiate.

*Dimensions.*—Length, 2.48 mm.; breadth, 2.00 mm.; thickness, 1.11 mm.

*Remarks.*—Several large fragmentary specimens are probably best referred to the genus *Darybella*. They are typified by the addition of the adult chambers on one side of the previous plane of coiling. Only one specimen displays a well-preserved aperture. This is large and radiate with no indication of a slit at the peripheral angle. According to Howe and Wallace (1932, p. 23) a slit at the peripheral angle is characteristic of this genus. Beck (1943, p. 596) recorded a much smaller but apparently similar form from the Cowlitz formation of Washington and suggested the possibility of establishing a new genus for those forms with a typical robuline aperture.

The present specimens show much variability and probably represent more than one species. Some have the last formed chambers

on the more convex side while in others the reverse occurs. Most of the specimens are much thinner than the figured specimen.

*Occurrence.*—Zone 3 in Porter shale near Porter, Washington.

*Repository.*—State Univ. Iowa, 9453 (figured specimen), 9454 (unfigured specimens).

Genus PLANULARIA Defrance, 1824
PLANULARIA MARKLEYANA Church
Plate 29, figure 13

*Planularia markleyana* CHURCH, 1931, *Figured in* Mining in California, vol. 27, no. 2, pp. 209, 211, pl. A, fig. 6, pl. B, figs. 1, 10; *Described in* 1943, California Dept. Nat. Resources, Bull. 118, pt. 2, p. 182.

*Dimensions.*—Minimum and maximum length, 2.03–3.30 mm.; breadth, 1.10–2.00 mm.; thickness, 0.63–0.73 mm.

*Remarks.*—This very large species is moderately rare in the present Porter samples. Apparently all of the specimens studied are megalospheric individuals. According to the description by Church, the megalospheric form is characterized by an unusually large initial chamber which stands out as a central knob. This feature is distinct in all present specimens. They are all incomplete, thus the length of the entire test may be considerably greater than the maximum stated above.

*Occurrence.*—Zones 1 to 5 in Porter shale near Porter, Washington, and known previously from the Markley formation of California.

*Figured specimen.*—State Univ. Iowa, 9455.

Genus MARGINULINA d'Orbigny, 1826
MARGINULINA ALAZANENSIS Nuttall
Plate 29, figure 4

*Marginulina alazanensis* NUTTALL, 1932, Jour. Paleontology, vol. 6, p. 13, pl. 3, figs. 3, 7.

*Dimensions.*—Minimum and maximum length, 1.31–1.91 mm.; diameter, 0.34–0.44 mm.

*Remarks.*—A thin section of one of several elongate specimens shows that the early chambers are coiled and the later chambers are arranged in a slightly arcuate elongate manner. The early sutures are strongly oblique whereas the adult ones are nearly normal to the long axis of the test. These specimens are comparable in all respects to *M. alazanensis* described and illustrated from the lower Oligocene of Mexico.

*Occurrence.*—Zone 3 in Porter shale near Porter, Washington, and known previously from the Alazan shale, Vera Cruz state, Mexico, the Oligocene of Cuba, and the Tranquilla shale of Panama.

*Hypotypes.*—State Univ. Iowa, 9456 (figured specimen), 9457 (unfigured specimens).

Genus VAGINULINOPSIS Silvestri, 1904
VAGINULINOPSIS SAUNDERSI
(Hanna and Hanna)
Plate 30, figures 19–22

*Vaginulinopsis saundersi* (Hanna and Hanna), BECK, 1943, Jour. Paleontology, vol. 17, p. 598, pl. 105, figs. 1, 2, 4, 5, 10.
*Vaginulina elegans* d'Orbigny var. *mexicana* NUTTALL, 1932, Jour. Paleontology, vol. 6, p. 16, pl. 3, figs. 12, 16.—PALMER and BERMUDEZ,

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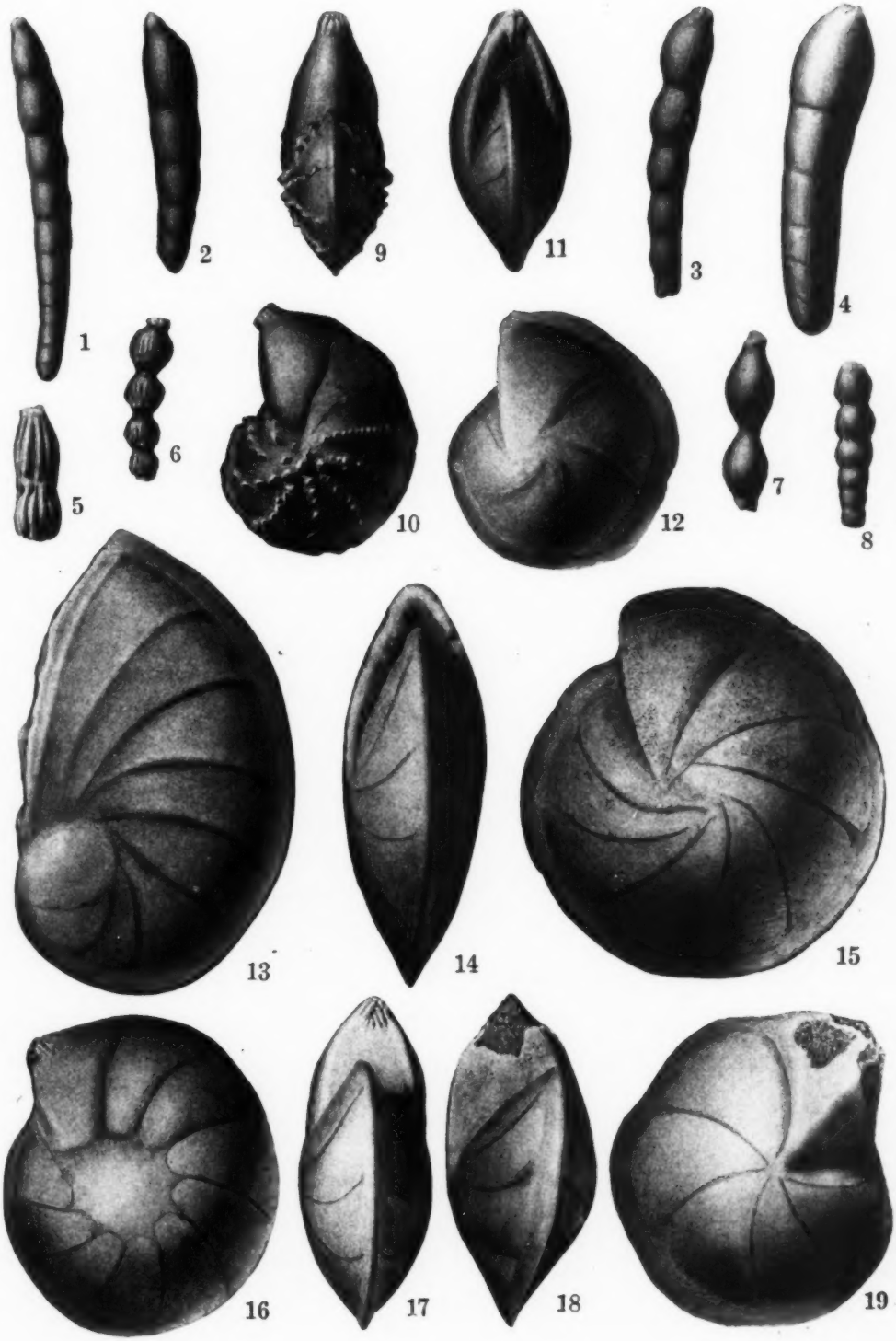
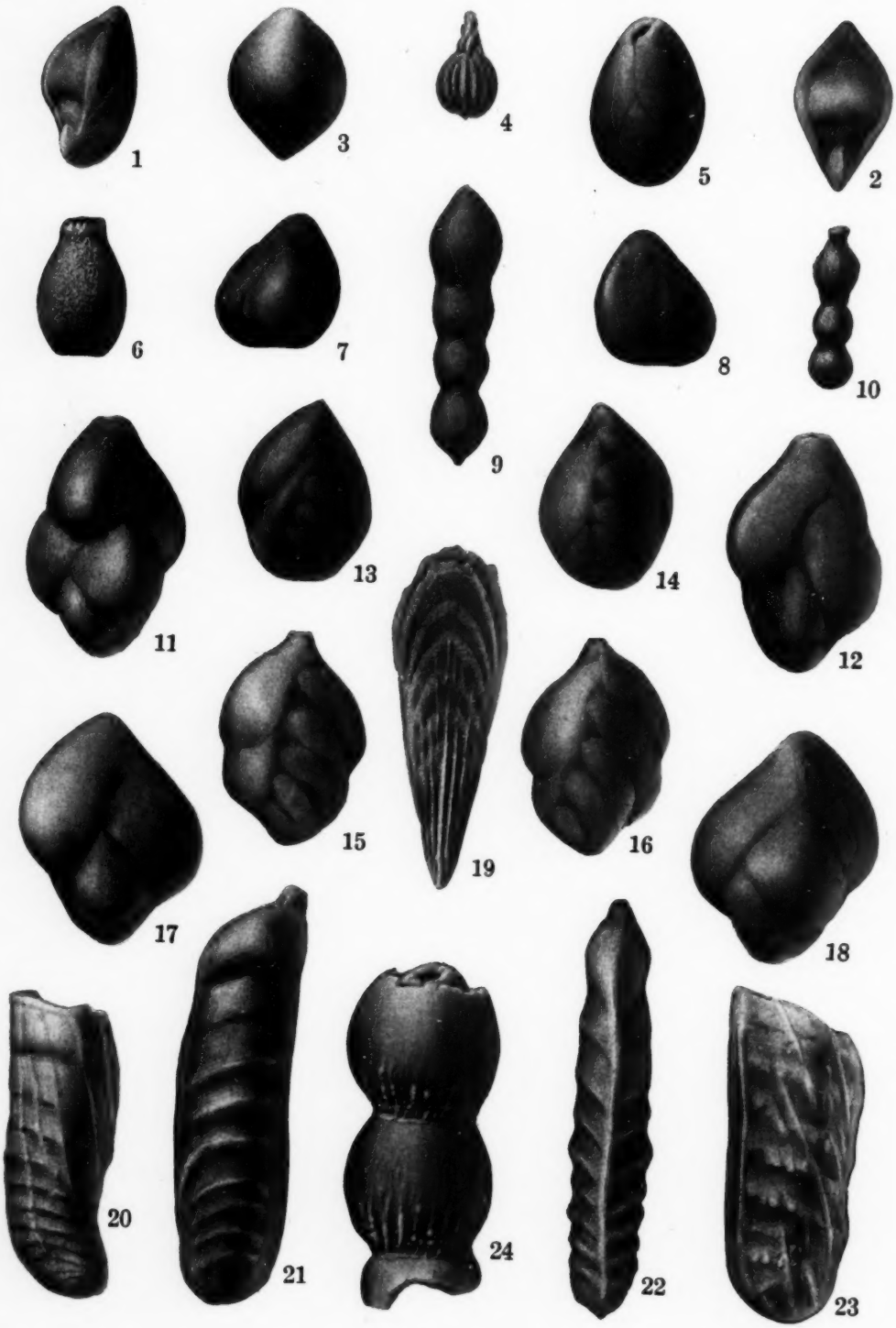
EXPLANATION OF PLATE 29

All specimens from the Porter shale, Grays Harbor County, Washington.

FIGS. *1*—*Dentalina* cf. *D. vagina* Stache, ×25. (p. 165)
*2*—*Dentalina communis* (d'Orbigny), ×25. (p. 166)
*3*—*Dentalina* sp. a., ×25. (p. 166)
*4*—*Marginulina alazanensis* Nuttall, ×25. (p. 164)
*5*—*Dentalina?* sp. b., ×25. (p. 166)
*6*—*Dentalina* cf. *D. adolphina* d'Orbigny, ×25. (p. 166)
*7*—*Dentalina* sp. c., ×25. (p. 167)
*8*—*Dentalina?* sp. d., ×25. (p. 167)
*9, 10*—*Robulus gutticostatus cocoaensis* (Cushman), ×25. (p. 162)
*11, 12*—*Robulus limbosus hockleyensis* (Cushman and Applin), ×25. (p. 162)
*13*—*Planularia markleyana* Church, ×20. (p. 164)
*14, 15*—*Robulus chehalisensis* Rau, n. sp., Holotype, ×25. (p. 162)
*16, 17*—*Robulus texanus* (Cushman and Applin), ×25. (p. 163)
*18, 19*—*Darbyella?* sp., ×20. (p. 163)




Rau, Early Tertiary Foraminifera




Rau, Early Tertiary Foraminifera

1936, Soc. cubana histora nat. Mem., vol. 10, p. 277, pl. 14, figs. 23, 24.

*Dimensions.*—Minimum and maximum length, 1.27–3.12 mm.; breadth, 0.63–0.77 mm.; thickness, 0.34–0.50 mm.

*Remarks.*—Beck carefully studied this species and found that it varies greatly in form. In addition to the variations mentioned by him, some of the specimens examined in the present study display ornamental costae almost normal to the raised sutures. Both megalospheric and microspheric forms are probably represented in the Porter material. Those specimens referred to as megalospheric have a large proloculum which is followed by slightly coiled, almost mature chambers. Those considered to be microspheric are more strongly curved and narrower in the early stage of development than the megalospheric forms. The initial chamber is very small and is followed by numerous, considerably coiled, immature chambers.

A form described and illustrated by Nuttall as *Vaginulina elegans mexicana* appears to be essentially identical with many of the present specimens as well as with those figured by Beck. The genera *Vaginulina* and *Vaginulinopsis* have many characteristics in common, but generally differ in that *Vaginulina* is strongly compressed, and usually has one straight and one convex edge whereas *Vaginulinopsis* is less compressed with both edges nearly straight and parallel. Because of these distinctions, the author believes the present specimens should be referred to *Vaginulinopsis*.

*Occurrence.*—Zone 3 in Porter shale near Porter, Washington. This form is also known from the Cowlitz formation of Washington, the Alazan shale of Vera Cruz state, Mexico, and the Oligocene of Cuba.

*Figured specimens.*—State Univ. Iowa, 9458.

### Genus DENTALINA d'Orbigny, 1826

### DENTALINA cf. D. VAGINA Stache

Plate 29, figure 1

*?Dentalina vagina* STACHE, 1865, Novara Exped. 1857–1859, wien Österreich, Geol. Theil, Bd. 1, abt. 2, p. 206, pl. 22, fig. 34.—CUSHMAN and DUSENBURY, 1934, Cushman Lab. Foram. Research Contr., vol. 10, pt. 3, p. 55, pl. 7, fig. 16.

*Dimensions.*—Minimum and maximum length, 1.12–2.08 mm.; diameter, 0.21-0.26 mm.

*Remarks.*—Several elongate specimens which display considerable variation have many characteristics of *D. vagina*. The small final chamber of the figured specimen is not typical of this group as in all others, the apertural chamber has the greatest diameter. This specimen is figured because it is the only complete one in the collection. A specimen figured questionably as this species by Cushman and Dusenbury from the Eocene of California seems very similar to

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EXPLANATION OF PLATE 30

All specimens from the Porter shale, Grays Harbor County, Washington.

FIGS. *1, 2—Saracenaria schencki* Cushman and Hobson, ×25. (p. 168)
*3—Pseudoglandulina inflata* (Bornemann), ×25. (p. 168)
*4—Lagena* sp., ×35. (p. 169)
*5—Globobulimina* cf. *G. pacifica* Cushman, ×35. (p. 171)
*6—Nodosaria?* sp., ×25. (p. 168)
*7, 8—Guttulina irregularis* d'Orbigny, ×25. (p. 169)
*9—Nodosaria grandis* Reuss, ×25. (p. 167)
*10—Siphonodosaria frizzelli* Rau, n. sp., Holotype, ×25. (p. 171)
*11, 12—Guttulina hantkeni* Cushman and Ozawa, ×25. (p. 169)
*13, 14—Sigmomorphina schencki* Cushman and Ozawa, ×25. (p. 170)
*15, 16—Sigmomorphina undulata* Rau, n. sp., Holotype, ×25. (p. 170)
*17, 18—Guttulina frankei* Cushman and Ozawa, ×25. (p. 170)
*19—Plectofrondicularia packardi multilineata* Cushman and Simonson, ×35. (p. 171)
*20–23—Vaginulinopsis saundersi* (Hanna and Hanna), 3 specimens. *20*, microspheric form. *21, 22, 23*, megalospheric forms, ×25. (p. 164)
*24—Dentalina dusenburyi* Beck, ×25. (p. 167)

some of the present specimens. Because the group of specimens under consideration is quite meager, a definite classification is not possible.

*Occurrence.*—Zone 3 in Porter shale near Porter, Washington. The type of *D. vagina* came from the Eocene of Auckland province, New Zealand. A questionable form is also recorded from the Poway conglomerate of southern California.

*Figured specimen.*—State Univ. Iowa, 9459.

### DENTALINA sp. A
Plate 29, figure 3

*Description.*—Test slightly arcuate, cylindrical, tapering gently from initial end to the center of the last-formed chamber where it is of maximum breadth, initial end spinose, chambers as many as six, slightly longer than broad throughout development, all very slightly inflated; sutures depressed, normal to the axis of elongation, frequently with very fine costae parallel to the long axis of the test; walls smooth; aperture radiate and slightly produced.

Length of figured fragment, 1.70 mm.; breadth, 0.30 mm.

*Remarks.*—This form appears most similar to *D. vagina* Stache, described and illustrated from the Eocene of New Zealand in Ellis and Messina's Catalogue of Foraminifera and also figured questionably from the Eocene of California by Cushman and Dusenbury (1934, p. 55, pl. 7, fig. 16). However, it differs in that the younger and adult chambers are nearly the same in shape and size and the proloculum is frequently slightly larger than the following chambers. The adult chambers, however, are similar in shape and size to the adult chambers of *D. vagina*. It may be that the specimens under consideration represent the megalospheric form of that species but more material must be examined before definite conclusions can be drawn regarding their affinities.

*Occurrence.*—Zones 2 and 3 in Porter shale near Porter, Washington.

*Repository.*—State Univ. Iowa, 9461 (figured specimen), 9462 (unfigured specimens).

### DENTALINA COMMUNIS (d'Orbigny)
Plate 29, figure 2

*Nodosaria communis* D'ORBIGNY, 1826, Soc. Annales sci. nat., vol. 7, p. 254, no. 35.
*Dentalina communis* BECK, 1943, Jour. Paleontology, vol. 17, p. 598, pl. 105, fig. 22.

*Dimensions.*—Length, 1.51 mm.; diameter, 0.30 mm.

*Remarks.*—This slightly arcuate form agrees well with the numerous published descriptions and illustrations of the widespread species *D. communis*. With the exception of fewer chambers, the present specimens compare favorably in every respect with Beck's description. Specimens are rare in the present Porter shale samples.

*Occurrence.*—Zones 2 and 5 in Porter shale near Porter, Washington, and known previously from many localities of both this continent and abroad occurring statigraphically from Eocene to Recent.

*Figured specimen.*—State Univ. Iowa, 9460.

### DENTALINA? sp. B
Plate 29, figure 5

*Dimensions.*—Length of fragment, 0.67 mm.; diameter, 0.28 mm.

*Remarks.*—A single fragmentary specimen is distinct from all other elongate types of this collection in that the walls of each chamber are strongly ornamented with coarse costae. This form may belong in the genus *Nodosaria*, but until more material is available its generic affinities will remain uncertain.

*Occurrence.*—Zone 5 in Porter shale near Porter, Washington.

*Figured specimen.*—State Univ. Iowa, 9463.

### DENTALINA cf. D. ADOLPHINA d'Orbigny
Plate 29, figure 6

*?Dentalina adolphina* D'ORBIGNY, 1846, Foram. Foss. Bass. Tert. Vienne, p. 51, pl. 2, figs. 18–20.—CUSHMAN and SCHENCK, 1928, Univ. California Publ. Bull. Dept. Geol. Sci., vol. 17, p. 308, pl. 42, fig. 6.—CUSHMAN, 1929, Cushman Lab. Foram. Research Contr., vol. 5, pt. 4, p. 86, pl. 13, figs. 3, 4.—NUTTALL, 1932, Jour. Paleontology, vol. 6, p. 14.—HADLEY, 1934, Am. Paleontology Bull., vol. 20, no. 70A, p. 10.—CUSHMAN, 1935, U. S. Geol. Survey Prof. Paper 181, p. 21, pl. 8, figs. 11, 12.
*? Nodosaria adolphina* CUSHMAN and HANNA, G. D., 1927, California Acad. Sci., ser. 4, vol. 16, p. 213, pl. 13, figs. 8, 9.

*Dimensions.*—Length, 0.93 mm.; diameter, 0.26 mm.

*Remarks.*—There are a few specimens in the Porter fauna which display considerable resemblance to the widespread species *D. adolphina*. However, this form is represented in the available Porter material by only a few incomplete specimens and thus specific identification can not be definitely established.

*Occurrence.*—Zone 4 in Porter shale near Porter, Washington. *D. adolphina*, originally described from the Miocene of the Vienna Basin, has been recorded from numerous other Tertiary localities abroad, especially the Eocene, Oligocene, and Miocene of the Caribbean region and Mexico. It is also known from the Bastendorf formation of western Oregon, the Kreyenhagen shale of California, and the Jackson formation of South Carolina.

*Figured specimen.*—State Univ. Iowa, 9464.

DENTALINA sp. C
Plate 29, figure 7

*Dimensions.*—Length of fragment, 1.00 mm.; diameter, 0.28 mm.

*Remarks.*—Several two-chambered fragments have sutures which are slightly oblique and chambers arranged in an arcuate manner and on these bases they are referred to *Dentalina*. Fragments from the Eocene of Washington, figured as *Nodosaria* cf. *N. pyrula* d'Orbigny by Beck (1943, p. 599, figs. 19, 21) bear a striking resemblance to the specimens studied here. However, the present material is insufficient to permit a positive identification.

*Occurrence.*—Zone 3 in Porter shale near Porter, Washington.

*Repository.*—State Univ. Iowa, 9465 (figured specimen), 9466 (unfigured specimen).

DENTALINA DUSENBURYI Beck
Plate 30, figure 24

*Dentalina dusenburyi* BECK, 1943, Jour. Paleontology, vol. 17, p. 599, pl. 105, figs. 20, 23.

*Dimensions.*—Length of fragment, 1.95 mm.; diameter, 0.90 mm.

*Remarks.*—A number of large broken specimens displaying distinct costae in the sutural areas are best referred to *D. dusenburyi*. A fragmentary specimen figured by Cushman and Frizzell (1943), p. 83, pl. 14 fig. 8) as *Dentalina* sp. B from the type area of the Lincoln formation appears similar to Beck's form, as well as the specimens of this study, in that it displays the same typical costae at the sutural area.

*Occurrence.*—Zones 2 and 4 in Porter shale near Porter, Washington, and known previously from the Cowlitz formation of Washington.

*Figured specimen.*—State Univ. Iowa, 9467.

DENTALINA? sp. D
Plate 29, figure 8

*Dimensions.*—Length, 0.90 mm.; diameter, 0.17 mm.

*Remarks.*—The Porter material contains a single fragmentary specimen with both initial and apertural chambers missing which is perhaps best referred to *Dentalina*. It is distinct from any other specimen in the collections in that it is small and the sutural areas are strongly ornamented with costae. *D. dusenburyi* Beck is ornamented with costae at the sutural areas but differs in that the costae extend up on to the base of each chamber and it is much larger than the form under consideration. This broken specimen also resembles *D. sandbergeri* Reuss figured from the Oligocene of Germany in Ellis and Messina's Catalogue of Foraminifera, but differs in that it is not arcuate and is smaller. *D. buchi* Reuss, figured from the Eocene of Germany in Ellis and Messina's Catalogue, also is similar to the present specimen but differs in that the early chambers are longer with respect to their diameter. Until more material is studied, it is impossible to place this specimen.

*Occurrence.*—Zone 4 in Porter shale near Porter, Washington.

*Figured specimen.*—State Univ. Iowa, 9468.

Genus NODOSARIA Lamarck, 1812
NODOSARIA GRANDIS Reuss
Plate 30, figure 9

*Nodosaria grandis* REUSS, 1866, K. Akad. Wiss. Wien, Math. -Naturw. Cl., Denkschr., Wien Österreich, vol. 25, pt. 1, p. 131, pl. 1, figs. 26–28.

*Dimensions.*—Minimum and maximum length, 0.80–1.61 mm.; diameter, 0.34–0.50 mm.

*Remarks.*—Several well-preserved specimens seem almost identical to *N. grandis* described and illustrated from the Middle Oligocene of Germany. They possess a spined initial chamber which is larger than the following one and a slightly tilted, ovoid apertural chamber with the aperture radiating subterminally—characteristics typical of this species. Beck (1943, p. 599, pl. 105, fig. 14) has figured a fragmentary specimen from the Eocene of Washington as *Dentalina* cf. *D. dusenburyi* which appears very similar to the present specimens.

*Occurrence.*—Zones 1 to 4 in Porter shale near Porter, Washington, and known previously from several Tertiary localities of Europe.

*Hypotype.*—State Univ. Iowa, 9469 (figured specimen), 9470 (unfigured specimens).

NODOSARIA? sp.
Plate 30, figure 6

*Dimensions.*—Length, 0.85 mm.; diameter, 0.55 mm.

*Remarks.*—Several fragmentary specimens differ from any other *Nodosaria* or *Dentalina* of this study in that the walls are roughened with a very fine hispid ornamentation. An unfigured specimen indicates that the initial chamber is spherical with no spine and slightly larger than the following chamber. Apparently the chambers become somewhat elongate in the later stage of development as represented by the figured fragment. This form is very rare in the Porter material.

*Occurrence.*—Zone 3 in Porter shale near Porter, Washington.

*Figured specimen.*—State Univ. Iowa, 9471.

Genus PSEUDOGLANDULINA Cushman, 1929
PSEUDOGLANDULINA INFLATA (Bornemann)
Plate 30, figure 3

*Glandulina inflata* BORNEMANN, 1855, Zeitsch. deutsch. geol. Ges., vol. 7, p. 320, pl. 12, figs. 6, 7.

*Pseudoglandulina inflata* CUSHMAN and FRIZZELL, 1943, Cushman Lab. Foram. Research Contr., vol. 19, pt. 4, p. 84, pl. 14, fig. 14.

*Dimensions.*—Minimum and maximum length, 0.55–0.87 mm.; diameter, 0.42–0.66 mm.

*Remarks.*—This species is common and well-distributed in the Porter samples. Detling (1946, p. 354, pl. 48, fig. 8) described and illustrated a form as *P. turbinata* from the Bastendorf formation of Oregon which appears very similar to the present specimens and a comparison of the actual specimens might prove them to be conspecific.

*Occurrence.*—Zones 1 to 5 in Porter shale near Porter, Washington, and known previously from the Lincoln formation (type locality) of Washington. This form was originally recorded from the Oligocene of Europe.

*Figured specimen.*—State Univ. Iowa, 9472.

Genus SARACENARIA Defrance, 1824
SARACENARIA SCHENCKI
Cushman and Hobson
Plate 30, figures 1, 2

*Saracenaria schencki* CUSHMAN and HOBSON, 1935, Cushman Lab. Foram. Research Contr., vol. 11, pt. 3, p. 57, pl. 8, figs. 11a, b.—PALMER and BERMUDEZ, 1936, Soc. cubana historia nat. Mem., vol. 10, p. 276.—KLEINPELL, 1938, Miocene Stratig. California, p. 222.—CUSHMAN and ELLISOR, 1945, Jour. Paleontology, vol. 19, p. 557, pl. 74, fig. 12.

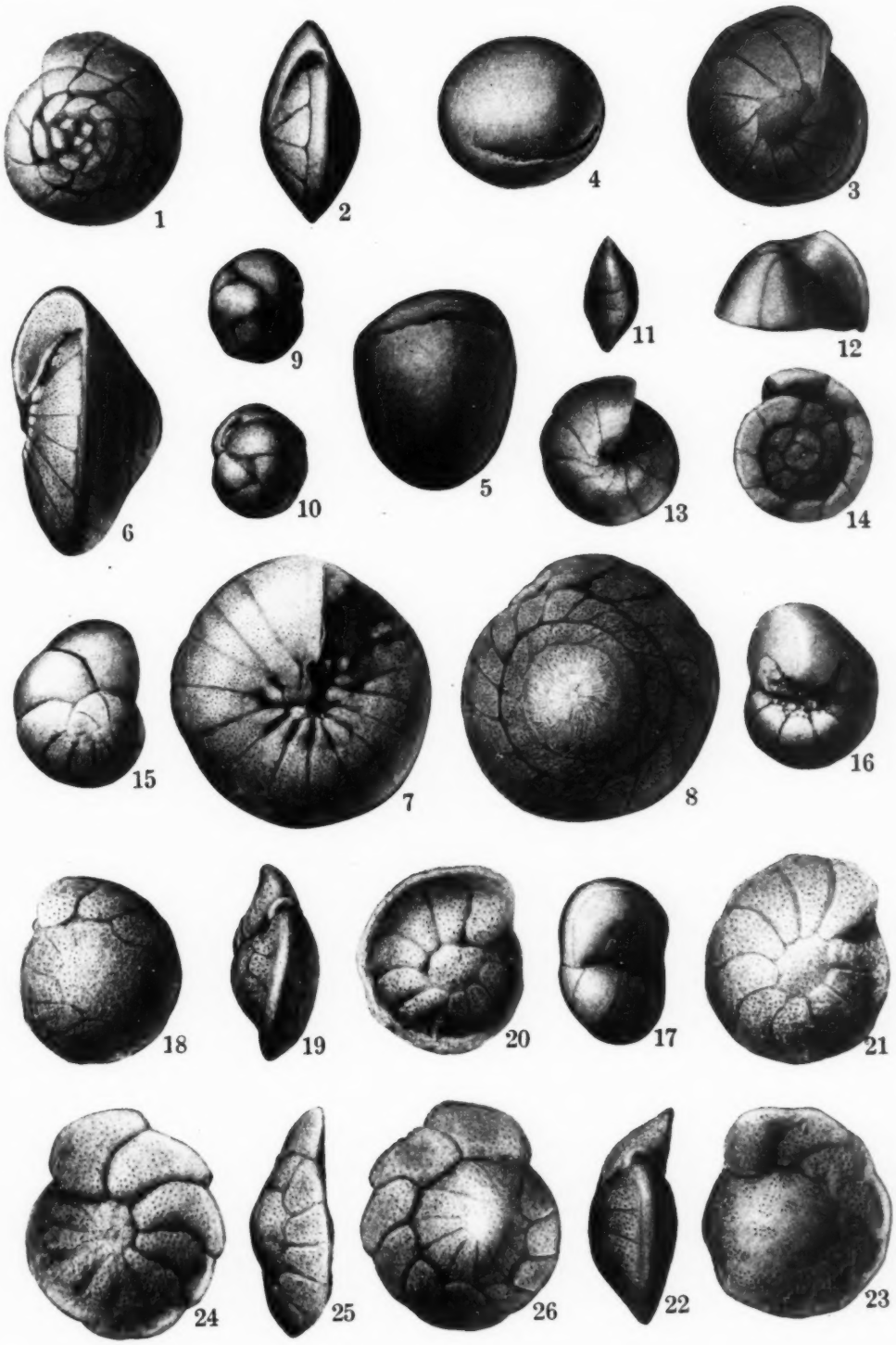
*Dimensions.*—Minimum and maximum length, 0.63–1.00 mm.; breadth, 0.42–0.54 mm.; thickness, 0.34–0.52 mm.

*Remarks.*—There are a number of specimens in the Porter material which possess the fundamental characteristics of *S. schencki*. The general shape of the test, arrangement of chambers, and the radiate aperture with a

EXPLANATION OF PLATE 31

All specimens from the Porter shale, Grays Harbor County, Washington.

FIGS. *1–3—Epistomina eocenica* Cushman and M. A. Hanna, ×25. (p. 172)
*4, 5—Allomorphina* cf. *A. macrostomata* Karrer, ×25 (p. 173)
*6–8—Eponides kleinpelli* Cushman and Frizzell, ×25. (p. 172)
*9–11—Cassidulina galvinensis* Cushman and Frizzell, ×35. (p. 173)
*12–14—Gyroidina orbicularis planata* Cushman, ×35. (p. 171)
*15–17—Ceratobulimina washburnei* Cushman and Schenck, ×35. (p. 172)
*18–26—Cibicides elmaensis* Rau, n. sp., 3 syntypes, ×35. (p. 173)




Rau, Early Tertiary Foraminifera

distinct slit in the apertural face all coincide well with the published description and illustrations of the holotype. However, the keel is not at all well developed and in some specimens it is nearly absent. Others display a rather thick, blunt extension of the periphery. This is the only apparent major variation from the type of *S. schencki* that is shown in the Porter specimens. Several specimens, which are somewhat narrower but similar in every other respect to the typical form, are also referred to this species.

*Occurrence.*—Zone 3 in Porter shale near Porter, Washington, and known previously from the Temblor, Vaqueros, and upper San Lorenzo formations of California, the Lower and Upper Oligocene of Cuba, and the Anahuac formation of Texas.

*Hypotypes.*—State Univ. Iowa, 9473 (figured specimen), 9474 (unfigured specimens).

### Genus LAGENA Walker and Jacob, 1798

### LAGENA sp.

Plate 30, figure 4

*Description.*—Test small, globular, with a long neck; chamber very slightly longer than broad, slightly more acute near the neck than at the base; walls very finely perforate, strongly ornamented with longitudinal, plate-like costae, approximately every other one extending from the top of the neck to very nearly the center of the base; short secondary ridges extending only over the broader portion of the chamber and lying between the long primary costae; a short spine at the center of the base; aperture indistinct.

Length of chamber, 0.26 mm.; diameter, 0.24 mm.; length of neck, 0.18 mm.

*Remarks.*—The outstanding features of this single, well-preserved specimen are the extremely long neck and the alternating primary and secondary costae. Cushman and Frizzell (1943, p. 84, pl. 14, fig. 11) have recorded a similar form as *Lagena* cf. *L. isabella* (d'Orbigny) from the type area of the Lincoln formation in Lewis County, Washington. The specimen of the present study differs in that the chamber is more nearly spherical and secondary costae are present. *L. costata*, recorded by numerous authors (*especially* Cushman, 1935, p. 23, pl. 9, figs. 7, 8), displays considerable resemblance to the present specimen but it apparently does not have secondary costae. *L. sulcata* (Walker and Jacob), known from the Choctawhatchee formation of Florida (Cushman, 1930, p. 31, pl. 5, fig. 10) and the Miocene of California (Cushman and Parker 1931, p. 6, pl. 1, fig. 20), is quite similar to the specimen under consideration. Secondary costae are shown on some but the chamber is generally elongate and the costae are coarser. Although the Porter specimen seems most similar to *L. sulcata*, it is impossible to identify it as such because there are numerous other similar species and only one specimen is available for study.

*Occurrence.*—Zone 4 in Porter shale near Porter, Washington.

*Figured specimen.*—State Univ. Iowa, 9475.

### Family POLYMORPHINIDAE

### Genus GUTTULINA d'Orbigny, 1839

### GUTTULINA IRREGULARIS (d'Orbigny)

Plate 30, figures 7, 8

*Guttulina irregularis* (d'Orbigny), CUSHMAN and OZAWA, 1930, U. S. Nat. Mus. Proc., vol. 77, art. 6, pp. 25–27, pl. 7, figs. 1, 2.—CUSHMAN and THOMAS, 1929, Jour. Paleontology, vol. 3, p. 177, pl. 23, figs. 2a, c.

*Dimensions.*—Minimum and maximum length, 0.59–0.81 mm.; breadth, 0.51–0.74 mm.; thickness, 0.34–0.54 mm.

*Remarks.*—A number of specimens appear similar to several published illustrations of *G. irregularis*. Cushman and Ozawa consider several formerly described forms as belonging in this species and point out that the variations are due to various stages of development. The specimen here illustrated probably represents an early stage.

*Occurrence.*—Zones 1 to 3 in Porter shale near Porter, Washington, and known to have a wide geographic distribution both in the United States and abroad, occurring stratigraphically from Cretaceous to Recent.

*Figured specimen.*—State Univ. Iowa, 9476.

### GUTTULINA HANTKENI Cushman and Ozawa

Plate 30, figures 11, 12

*Polymorphina acuta* HANTKEN, 1875, Mitth. Jahrb. K. Ungar. geol. Anstalt, vol. 4, p. 60, pl. 8, fig. 4.

*Guttulina hantkeni* CUSHMAN and OZAWA, 1930,

U. S. Nat. Mus. Proc., vol. 77, art. 6, p. 33, pl. 5, figs. 4–6.

*Dimensions.*—Length, 1.41 mm.; breadth, 0.95 mm.; thickness, 0.77 mm.

*Remarks.*—A single essentially perfect specimen appears similar to the holotype of *G. hantkeni*, described and illustrated by Cushman and Ozawa from the Eocene of Hungary.

*Occurrence.*—Zone 5 in Porter shale near Porter, Washington, and also reported from the Claiborne group of New Jersey and Louisiana, the Cretaceous of New Jersey, the Poway conglomerate of southern California, and the Eocene of Hungary and Holland.

*Figured specimen.*—State Univ. Iowa, 9477.

GUTTULINA FRANKEI Cushman and Ozawa
Plate 30, figures 17, 18

*Polymorphina lactea* Walker and Jacob, var. *cuspidata* FRANKE, 1925, Abhandl. Ber. Mus. Naturw-und-Heimatkunde und Nat. Ver., Bd. 4, Heft 2, p. 177, pl. 6, fig. 46b.

*Guttulina frankei* CUSHMAN and OZAWA, 1930, U. S. Nat. Mus. Proc., vol. 77, art. 6, p. 28, pl. 4, fig. 1.—CUSHMAN and FRIZZELL, 1943, Cushman Lab. Foram. Research Contr., pt. 4, vol. 19, p. 84, figs. 17, 18.

*Dimensions.*—Minimum and maximum length, 0.80–1.30 mm.; breadth, 0.63–1.02 mm.; thickness, 0.55–0.84 mm.

*Remarks.*—A number of rather variable specimens having many essential characteristics of *G. frankei* occur in several of the Porter samples. Some very closely resemble those described and illustrated by Cushman and Ozawa from the Middle Oligocene of Germany. Others show a definite gradation in form of which the extreme type is much larger, considerably wider, and with a somewhat greater apertural angle than the typical form. The figured specimen displays these extreme features.

*Occurrence.*—Zones 1 to 3 in Porter shale near Porter, Washington. This form has been previously recorded from the Lower and Middle Oligocene of Germany, and the Lincoln formation (type locality) of Washington.

*Figured specimen.*—State Univ. Iowa, 9478.

Genus SIGMOMORPHINA Cushman and Ozawa, 1928

SIGMOMORPHINA SCHENCKI Cushman and Ozawa
Plate 30, figures 13, 14

*Sigmomorphina schencki* Cushman and Ozawa, 1930, U. S. Nat. Mus. Proc., vol. 77, art. 6, p. 133, pl. 35, figs. 6a, b.

*Dimensions.*—Minimum and maximum length, 0.80–1.07 mm.; breadth, 0.63–0.78 mm.; thickness, 0.34–0.40 mm.

*Remarks.*—Several broadly ovate specimens are best referred to *S. schencki*. They differ from the holotype in that the apertural end is slightly more acute but in all other respects, they are quite similar to the type. Cushman and Frizzell (1943, p. 85, pl. 14, fig. 20) have reported the occurrence of *S. cubensis* Cushman and Bermudez from the type area of the Lincoln formation in Lewis County, Washington. In general shape, the present specimens appear somewhat similar to this form but lack the basal spine which typifies it.

*Occurrence.*—Zones 2 and 3 in Porter shale near Porter, Washington. The holotype is from the Keasey shale of Oregon.

*Figured specimen.*—State Univ. Iowa, 9479.

SIGMOMORPHINA UNDULATA Rau, n. sp.
Plate 30, figures 15, 16

*Description.*—Test compressed, somewhat diagonally quadrangular, with apertural and basal angles rather acute, the other angles broadly rounded, periphery irregular, broadly undulate, greatest width near the middle, chambers elongate, slightly embracing, arranged in a sigmoid, clockwise series, each succeeding chamber equally removed from the base; sutures distinct, translucent, very slightly depressed between last formed chambers; walls smooth; aperture radiate, at the end of a short neck.

Length, 1.30 mm.; breadth, 1.00 mm.; thickness, 0.43 mm.

*Remarks.*—A number of excellently preserved specimens are quadrangular in shape and possess a broadly undulate periphery. *S. kuromatunaiensis* Asano, listed in Ellis and Messina's Catalogue of Foraminifera, from the Pliocene of Japan, appears similar

in many respects but differs in that it is considerably larger.

*Occurrence.*—Zone 5 in Porter shale near Porter, Washington.

*Holotype.*—State Univ. Iowa, 9480.

Family HETEROHELICIDAE

Genus PLECTOFRONDICULARIA Liebus, 1903

PLECTOFRONDICULARIA PACKARDI MULTILINEATA Cushman and Simonson

Plate 30, figure 19

*Plectofrondicularia packardi* Cushman and Schenck var. *multilineata* CUSHMAN and SIMONSON, 1944, Jour. Paleontology, vol. 18, p. 197, pl. 32, figs. 2-4.—DETLING, 1946, Jour. Paleontology, vol. 20, p. 355, pl. 49, figs. 3, 5.

*Dimensions.*—Length, 1.45 mm.; breadth, 0.48 mm.; thickness, 0.14 mm.

*Remarks.*—This form, although somewhat rare, occurs consistently throughout the present material. Numerous thin, long costae and limbate sutures are present and typify this species.

*Occurrence.*—Zones 1 to 5 in Porter shale near Porter, Washington, and known previously from the Tumey formation of California and the Coaledo and Bastendorf formations of Oregon.

*Figured specimen.*—State Univ. Iowa, 9481.

Family BULIMINIDAE

Genus GLOBOBULIMINA Cushman, 1927

GLOBOBULIMINA cf. G. PACIFICA Cushman

Plate 30, figure 5

*?Globobulimina pacifica* CUSHMAN, 1927, Cushman Lab. Foram. Research Contr., vol. 3, pt. 1, p. 67, pl. 4, fig. 12; 1927, Bull. Scripps Instit. Oceanography, Tech. Ser., vol. 1, p. 153, pl. 3, fig. 1.—CUSHMAN and JARVIS, 1930, Jour. Paleontology, vol. 4, p. 362, pl. 33, fig. 6.—CUSHMAN and STEWART, R. E. and K. C., 1930, San Diego Soc. Nat. History Trans., vol. 6, p. 66, pl. 5, fig. 4.—CUSHMAN and LAIMING, 1931, Jour. Paleontology, vol. 5, p. 108, pl. 12, figs. 1a, b.—CUSHMAN and HOBSON, 1935, Cushman Lab. Foram. Research Contr , vol. 11, pt. 3, p. 62, pl. 9, figs. 3a, b.

*Dimensions.*—Length, 0.70 mm.; breadth, 0.48 mm.; thickness, 0.46 mm.

*Remarks.*—Several subglobular specimens have a loop-shaped aperture and an exterior which is made up of three chambers. The sutures are indistinct; walls very thin and finely perforate and the aperture is distinctly bordered, but devoid of any dentition. The thin delicate tests are not well preserved and, therefore, identification is uncertain.

*Occurrence.*—Zone 2 in Porter shale near Porter, Washington. *G. pacifica* has a wide geographic distribution and is known stratigraphically from Eocene to Recent. It has been reported from Oligocene to Recent in California, the Miocene of Florida, numerous localities from Upper Eocene to Pliocene in the Caribbean region, and in Recent deposits off the west coast of North America.

*Figured specimen.*—State Univ. Iowa, 9482.

Genus SIPHONODOSARIA A. Silvestri, 1924

SIPHONODOSARIA FRIZZELLI Rau, n. sp.

Plate 30, figure 10

*Description.*—Test elongate; 3 chambers, arranged in a rectilinear uniserial manner, separated by narrow necks, initial chamber slightly larger than the following one; walls rough and perforate; aperture a small round opening at the end of a distinctly lipped neck.

Length, 0.91 mm.; diameter, 0.26 mm.

*Remarks.*—This small form is uncommon in the present material but specimens are sufficiently numerous to show that they are distinct from any other *Siphonodosaria.*

*Occurrence.*—Zones 2 and 3 in Porter shale near Porter, Washington.

*Holotype.*—State Univ. Iowa, 9483.

Family ROTALIIDAE

Genus GYROIDINA d'Orbigny, 1826

GYROIDINA ORBICULARIS PLANATA Cushman

Plate 31, figures 12, 13, 14

*Gyroidina orbicularis* d'Orbigny var. *planata* CUSHMAN, 1935, U. S. Geol. Survey Prof. Paper 181, p. 45, pl. 18, fig. 3.—CUSHMAN and SIEGFUS, 1942, San Diego Soc. Nat. History Trans., vol. 9, p. 419, pl. 17, fig. 32.—CUSHMAN and FRIZZELL, 1943, Cushman Lab. Foram. Research Contr., vol. 19, pt. 4, p. 87, pl. 15, figs. 2-4.

*Dimensions.*—Minimum and maximum diameter, 0.38–0.62 mm.; height, 0.30–0.40 mm.

*Remarks.*—Numerous specimens display a very close relationship to the holotype of

*G. orbicularis planata* described and illustrated from the Upper Eocene of South Carolina. They have a flat dorsal side and a strongly convex ventral side which together form a sharp angle at the periphery. The last-formed coil falls slightly below the plane of the dorsal side. All sutures of the dorsal side are oblique. Furthermore, a large, low, lipped aperture extends from the periphery almost to the umbilicus. These features are typical of *G. orbicularis planata*.

*Occurrence.*—Zones 1 to 5 in Porter shale near Porter, Washington, and known previously from the Jackson formation of South Carolina, the lower part of the Kreyenhagen shale of California, and the Lincoln formation (type locality) of Washington.

*Figured specimen.*—State Univ. Iowa, 9484.

Genus EPONIDES Montfort, 1808

EPONIDES KLEINPELLI Cushman and Frizzell

Plate 31, figures 6, 7, 8

*Eponides kleinpelli* CUSHMAN and FRIZZELL, 1940, Cushman Lab. Foram. Research Contr., vol. 16, pt. 2, p. 42, pl. 8, figs. 11a, b, c.

*Dimensions.*—Minimum and maximum diameter, 0.76–1.53 mm.; height, 0.42–0.86 mm.

*Remarks.*—The illustrated specimen is slightly larger but essentially identical in every other respect to the holotype of *E. kleinpelli*. This species is rare in the Porter samples.

*Occurrence.*—Zones 3 and 4 in Porter shale near Porter, Washington. Holotype from the Lincoln formation (type locality) of Washington.

*Figured specimen.*—State Univ. Iowa, 9485.

Genus EPISTOMINA Terquem, 1883

EPISTOMINA EOCENICA Cushman and M. A. Hanna

Plate 31, figures 1, 2, 3

*Epistomina eocenica* CUSHMAN and M. A. HANNA, 1927, San Diego Soc. Nat. History, Trans., vol. 5, p. 53, pl. 5, figs. 4, 5.—CUSHMAN and SCHENCK, 1928, California Univ., Dept. Geol. Sci. Bull., vol. 17, p. 313, pl. 44, fig. 9.—WEINZIERL and APPLIN, 1929, Jour. Paleontology, vol. 3, p. 407.—CUSHMAN and MCMASTERS, 1936, Jour. Paleontology, vol. 10, p. 515. pl. 76, fig. 5.—CUSHMAN and FRIZZELL, 1943, Cushman Lab. Foram. Research Contr., vol. 19, pt. 4, p. 87, pl. 15, figs. 9, 10.—CUSHMAN, 1944, Jour. Paleontology, vol. 18, p. 202, pl. 34, fig. 6.

*Dimensions.*—Minimum and maximum diameter, 0.63–1.40 mm.; height, 0.34–0.80 mm.

*Remarks.*—The present specimens vary from the holotype of *E. eocenica* in that there are seven to as many as ten chambers in the last formed whorl instead of six, and a few are considerably larger. Otherwise, the specimens under consideration coincide well with the published description and illustrations of the holotype and hypotypes of *E. eocenica*.

*Occurrence.*—Zones 1 to 3 in Porter shale near Porter, Washington, and known previously from the La Jolla and Llajas formations of California, the Keasey formation of Oregon, the Claiborne formation of Texas, and the Lincoln formation (type locality) of Washington.

*Figured specimen.*—State Univ. Iowa, 9486.

Family CASSIDULINIDAE

Genus CERATOBULIMINA Toula, 1915

CERATOBULIMINA WASHBURNEI Cushman and Schenck

Plate 31, figures 15, 16, 17

*Ceratobulimina washburnei* CUSHMAN and SCHENCK, 1928, California Univ., Dept. Geol. Sci. Bull., vol. 17, no. 9, p. 314, pl. 45, figs. 1a, b, c.—BECK, 1943, Jour. Paleontology, vol. 17, p. 609, pl. 108, figs. 20, 24.

*Dimensions.*—Minimum and maximum length, 0.47–0.68 mm.; breadth, 0.38–0.54 mm.; thickness, 0.34–0.48 mm.

*Remarks.*—Several specimens are similar in every respect to the holotype of *C. washburnei*. All sutures are fairly distinct; a thin plate covers most of the aperture and the test is highly polished. This form is rare in the present Porter material.

*Occurrence.*—Zones 2 and 5 in Porter shale near Porter, Washington, and known previously from the Keasey shale of Oregon and the Cowlitz and Lincoln (type locality) formations of Washington.

*Figured specimen.*—State Univ. Iowa, 9487.

Genus CASSIDULINA d'Orbigny, 1826
CASSIDULINA GALVINENSIS
Cushman and Frizzell
Plate 31, figures 9, 10, 11

*Cassidulina galvinensis* CUSHMAN and FRIZZELL, 1940, Cushman Lab. Foram. Research Contr., vol. 16, pt. 2, p. 43, pl. 8, figs. 10a, b, c.

*Dimensions.*—Diameter, 0.48 mm.; thickness, 0.21 mm.

*Remarks.*—A few specimens seem essentially identical with the holotype of *C. galvinensis*. They are moderately rare in the present material.

*Occurrence.*—Zone 1 in Porter shale near Porter, Washington. Originally described and illustrated from the Lincoln formation (type locality) of Washington.

*Figured specimen.*—State Univ. Iowa, 9488.

Family CHILOSTOMELLIDAE
Genus ALLOMORPHINA Reuss, 1850
ALLOMORPHINA cf. A. MACROSTOMATA
Karrer
Plate 31, figures 4, 5

*?Allomorphina macrostomata* KARRER, 1861, k. Ak. Wiss. Wien, Sitz., vol. 44, p. 448, pl. 2, fig. 4.—NUTTALL, 1935, Jour. Paleontology, vol. 9, p. 129, pl. 15, fig. 28.—CUSHMAN and McMASTERS, 1936, Jour. Paleontology, vol. 10, p. 516, pl. 76, figs. 7a, b.

*Dimensions.*—Minimum and maximum length, 0.72–1.15 mm.; breadth, 0.59–0.93 mm.; thickness, 0.51–0.84 mm.

*Remarks.*—A number of ovoid specimens which have an elongate aperture normal to the long axis of the test, appear similar to a form figured by several authors as *A. macrostomata* Karrer. The major portion of the exterior is made up of the last formed chamber. Parts of two other chambers constitute the remaining surface of the test. The walls are very thin and the sutures are indistinct. The aperture is a long, narrow opening partially closed by a very narrow plate-like secondary growth. Specimens figured by Nuttall, and Cushman and McMasters are both strikingly similar to the present specimens. Because of the extremely thin, delicate test, only a few specimens are preserved well enough to be of any value for classification.

*Occurrence.*—Zones 2 and 3 in Porter shale near Porter, Washington. *A. macrostomata* is known from the Llajas formation of California, the Pauji formation of Venezuela, and several Tertiary localities in Europe.

*Figured specimen.*—State Univ. Iowa, 9489.

Family ANOMALINIDAE
Genus CIBICIDES Montfort, 1808
CIBICIDES ELMAENSIS Rau, n. sp.
Plate 31, figures 18–26

*Description.*—Test small to medium, subcircular, dorsal side very slightly convex to strongly convex with all whorls visible, ventral side nearly flat to strongly convex, frequently with a concave area near the periphery, usually with a distinct umbonal plug and with only the last formed whorl visible; periphery subacute and limbate; chambers 10 to 12 in last formed whorl, last 2 or 3 slightly inflated; sutures curved, usually limbate, slightly depressed or flush with the surface except the last two or three which are frequently strongly depressed; walls smooth, coarsely perforate; aperture a low arched opening at the base of the last formed chamber, slightly extended ventrally and continually dorsally as much as two or three chambers.

*Dimensions.*—Minimum and maximum diameter, 0.45–0.90 mm.; thickness, 0.22–0.40 mm.

*Remarks.*—These specimens display a wide variation in form. They are distinct from other previously described *Cibicides* in that the dorsal side is never flat but frequently strongly convex. The generally convex ventral side is usually modified by a concave or sunken area near the periphery. The specimens here studied may be divided into three general groups. The most common form apparently represents an intermediate stage between two extremes and is characterized by a biconvex test with a slightly concave or sunken area near the periphery on the ventral side. One extreme form appears almost planoconvex with the ventral side only slightly raised near the center and with some indication of a sunken area near the periphery. Its dorsal side is moderately convex. The other extreme is typified by a biconvex form which is decidedly more con-

vex on the ventral side with no indication of a sunken area near the periphery. These three forms are completely gradational as there are many intermediate specimens and are best referred to a single species.

*Occurrence.*—Zones 1 to 5 in Porter shale near Porter, Washington.

*Syntypes.*—State Univ. Iowa, 9490, 9491, 9492 (all figured specimens).

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# FORAMINIFERA FROM THE MIDDLE NEOCOMIAN OF THE NETHERLANDS

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ABSTRACT—Seventy-nine species of Foraminifera are recorded from the Middle Neocomian (Hauterivian, Lower Cretaceous) near the village of Glanerbrug, Province of Overijsel, Netherlands. Fourteen new species from this locality were described in a previous article. Two more new species are described here, and one new name is introduced.

## INTRODUCTION

DURING the study of Lower Cretaceous Foraminifera of the Netherlands, samples were collected by the author from the dark gray clays of the Middle Neocomian (Hauterivian) exposed in the Glanerbeek near Glanerbrug, Province of Overijsel, near boundary stone no. 849. This collection yielded a rich fauna, including the new species already described.

Part of the material was studied in the Micropaleontological Laboratory of the Netherlands State Geological Survey at Haarlem, another part in the Micropaleontological Laboratory of the Government Service for Mineral Research in Relizane, Algeria.

Little is known of the Foraminifera from the Middle Neocomian of Europe in general, and nothing of the Foraminifera of that age in America. The only publications containing descriptions or references to Middle Neocomian Foraminifera are: Reuss (1862), Eichenberg (1935), Roemer (1841, 1842) and Koch (1848) for Germany, and Chapman (1894), Burrows, Sherborn and Bailey (1890), and Sherlock (1914) for England.

The classification followed here is the same as that in my earlier publications and is based on the classification of Cushman (1940), emended according to the conceptions of Thalman, Glaessner, and Marie.

All described and figured specimens, holotypes and hypotypes are in the personal collection of the author; paratypes of the new species have been deposited in the Collection of the Netherlands State Geological Survey.

The illustrations are shaded camera lucida drawings by Jan Lammers. The text figures were drawn by Guy Oricelli. Bibliographic references are given as completely as possible. Detailed descriptions of old species are given only in cases where the earlier descriptions are inadequate or almost inaccessible.

## SYSTEMATIC DESCRIPTIONS

### Family RHIZAMMINIDAE
### Genus RHIZAMMINA Brady 1879
Genotype *Rhizammina algaeformis* Brady

#### RHIZAMMINA INDIVISA Brady

*Rhizammina indivisa* BRADY, 1884, Rept. Voy. Challenger, Zool., vol. 9, p. 277, pl. 29, figs. 5–7.

This species is rather rare in the Middle Neocomian of Glanerbrug. Recorded from the Lower Cretaceous of Holland, England, and Germany, from the Upper Cretaceous of Germany and America, from various beds in the Paleocene, Eocene, and Recent. For description and synonymy see ten Dam 1944, p. 72, for detailed discussion see Glaessner 1937, p. 355.

### Family RHEOPHACIDAE
### Subfamily RHEOPHACINAE
### Genus RHEOPHAX Montfort 1808
Genotype *Rheophax scorpiurus* Montfort

*Rheophax scorpiurus* MONTFORT, 1808, Conch. Syst., vol. 1, p. 330, 83rd genus, CUSHMAN, 1920, U. S. Nat. Mus. Bull. 104, pt. 2, p. 6.

This species is fairly common in the Middle Neocomian of Glanerbrug. Recorded fossil and recent from many formations. See Cushman (1920) for detailed discussion and synonymy.

Family AMMODISCIDAE
Subfamily AMMODISCINAE
Genus AMMODISCUS Reuss 1861
Genotype *Ammodiscus incertus* (d'Orbigny)
AMMODISCUS CRETACEUS (Reuss)

*Operculina cretaces* REUSS, 1845, Verst. Bohm. Kreideform., vol. 1, p. 35, pl. 13, figs. 64, 65.
*Ammodiscus cretaceous* SCHIJFSMA, 1946, Med. Geol. St., ser. C.V., no. 7, p. 26, pl. 6, fig. 7.
*Ammodiscus cretaceous* TEN DAM, 1946, Jour. Paleontology, vol. 20, p. 570.

This species is rather rare in the Middle Neocomian of Glanerbrug. Recorded from the Lower and Upper Cretaceous of Europe and America. For detailed description, discussion and synonymy see Schijfsma 1946.

Genus GLOMOSPIRA Rhezak 1888
Genotype *Trochammina gordialis* Jones and Parker
GLOMOSPIRA GORDIALIS (Jones and Parker)

*Trochammina squamata gordialis* JONES and PARKER, 1860, Quart. Jour. Geol. Soc., vol. 16, p. 304.
*Glomospira gordialis* TEN DAM, 1946, Jour. Paleontology, vol. 20, p. 570.

This well-known species has been recorded from the Cretaceous and Tertiary, and from recent seas all over the world. For references see ten Dam 1944, p. 77. Specimens are common in samples used in the present study.

Family LITUOLIDAE
Subfamily HAPLOPHRAGMIINAE
Genus HAPLOPHRAGMIUM Reuss 1860
Genotype *Spirolina aequalis* Roemer
HAPLOPHRAGMIUM AEQUALE (Roemer)

*Spirolina aequalis* ROEMER, 1841, Verst. Nordd. Kreidegeb., p. 98, pl. 15, fig. 27.
*Haplophragmium aequale* TEN DAM, 1946, Jour. Paleontology, vol. 20, p. 570.

This species has been recorded from the Middle Neocomian and perhaps from the Upper Neocomian of Germany, and specimens are rather common from Glanerbrug. It appears to be characteristic of the Middle Neocomian of northwestern Europe. For detailed discussion see ten Dam, 1946.

Genus HAPLOPHRAGMOIDES Cushman 1910
Genotype *Nonionina canariensis* d'Orbigny
HAPLOPHRAGMOIDES NEOCOMIANA (Chapman)

*Haplophragmium neocomianum* CHAPMAN, 1894, Quart. Jour. Geol. Soc., London, vol. 50, p. 695, pl. 34, fig. 2.
*Haplophragmoides neocomiana* TEN DAM, 1946, Jour. Paleontology, vol. 20, p. 571.

This species had been recorded from the Middle Neocomian of Surrey, England; and a few species have been collected at Glanerbrug. See ten Dam 1946 for detailed description and discussion.

Genus TRIPLASIA Reuss 1854
Genotype *Triplasia murchisoni* Reuss
TRIPLASIA GROSSERUGOSA ten Dam

*Triplasia grosserugosa* TEN DAM, 1946, Jour. Paleontology, vol. 20, p. 571.

This species has been described by the author in his already published paper from the same locality.

Family VERNEUILINIDAE
Genus TRITAXIA Reuss 1860
Genotype *Tritaxia tricarinata* Reuss
TRITAXIA PYRAMIDATA Reuss

*Tritaxia pyramidata* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 32, pl. 1, fig. 9.

This species has been recorded from the Albian and Cenomanian of Europe, and a few specimens were found in the Glanerbrug material.

Genus VERNEUILINA d'Orbigny 1840
Genotype *Verneuilina tricarinata* d'Orbigny
VERNEUILINA CHAPMANI ten Dam

*Bulimina polystropha* CHAPMAN (not Reuss), Quart. Jour. Geol. Soc. London, vol. 50, p. 701, pl. 34, fig. 5.
*Verneuilina chapmani* TEN DAM, 1946, Jour. Paleontology, vol. 20, p. 572.

This species has been recorded from the Middle Neocomian of England and a few specimens found at Glanerbrug. For description and discussion see ten Dam, 1946.

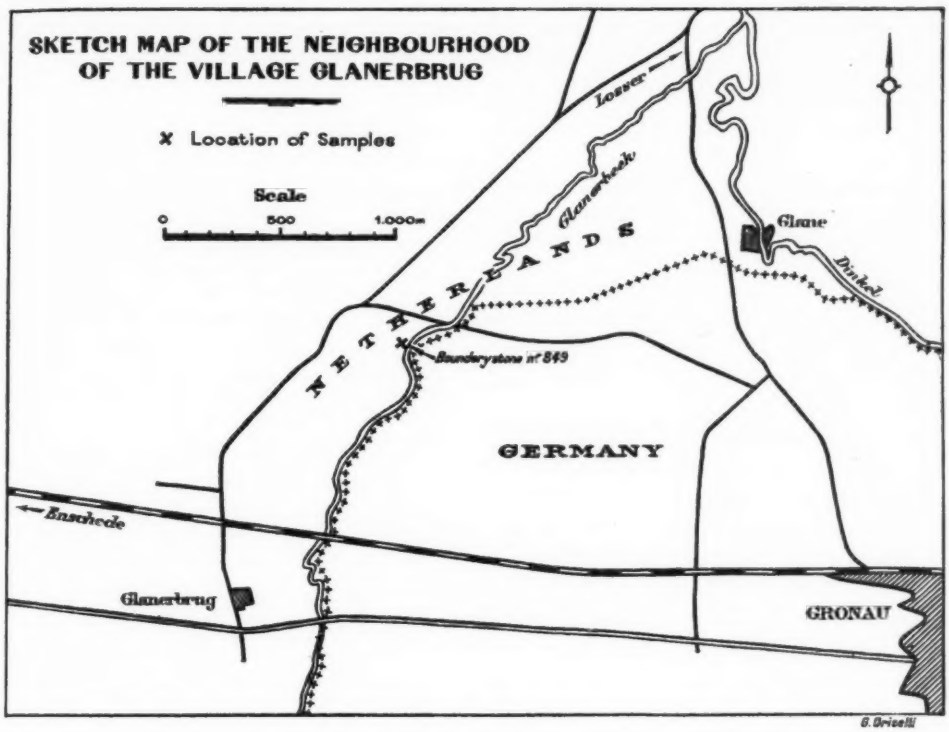



FIG. *1*

Family VALVULINIDAE
Genus MARSSONELLA Cushman 1933
Genotype *Gaudryina oxycona* Reuss
MARSSONELLA OXYCONA (Reuss)

*Gaudryina oxycona* REUSS, 1860, Sitz. Ber. Akad. Wiss. Wien, vol. 40, p. 229, pl. 12, fig. 3.

This well-known species which has been recorded from the Lower and Upper Cretaceous of Europe is represented by a few specimens in the Middle Neocomian of Glanerbrug.

Family TROCHAMMINIDAE
Subfamily TROCHAMMININAE
Genus TROCHAMMINA Jones and Parker 1859
Genotype *Nautilus inflatus* Montagu
TROCHAMMINA LIMBATA (Chapman)

*Trochammina squamata limbata* CHAPMAN, 1894, Quart. Jour. Geol. Soc. London, vol. 50, p. 697, pl. 34, fig. 4.
*Trochammina limbata* TEN DAM, 1946, Jour. Paleontology, vol. 20, p. 572, pl. 87, figs. 10a, b.

A few specimens of this species were found in the samples from Glanerbrug. It has been recorded from the Middle Neocomian of England, and a description and discussion may be found in ten Dam, 1946.

TROCHAMMINA NONIONINA (Reuss)

*Rotalia nonionina* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 81, pl. 10, fig. 2.
*Trochammina nonionina* TEN DAM, 1946, Jour. Paleontology, vol. 20, p. 573, pl. 87, figs. 11a–c.

Specimens of this species, previously reported from the Neocomian of Germany, were found at Glanerbrug. For description and discussion see ten Dam, 1946.

Family MILIOLIDAE
Genus NUBECULINA Cushman 1924
Genotype *Nubecularia divaricata* Brady
NUBECULINA NODULOSA (Chapman)

*Nubecularia nodulosa* CHAPMAN, Jour. Micr. Soc., ser. 2, vol. 11, p. 573, pl. 9, fig. 2.

Test free, elongate, uniserial. Chambers globular, separated by elongate narrow

necks. Wall imperforate, porcellaneous, with agglutinated foreign elements. Aperture circular, at end of elongated tubular neck.

*Dimensions.*—Diameter of chambers 0.3 mm.; length of specimen with four chambers 0.9 mm.

*Discussion.*—This species is distinguished by its very narrow and elongate necks, and seems closely related to *Nubeculina divaricata* Brady.

*Occurrence.*—Rather rare at Glanerbrug. Recorded from Albian of England and Holland, and from the Middle Neocomian of Germany.

Family OPHTHALMIDIIDAE
Subfamily NUBECULARIINAE
Genus NUBECULARIA Defrance 1825
Genotype *Nubecularia lucifuga* Defrance

NUBECULARIA TRILOCULINA ten Dam

*Nubecularia lucifuga* JONES and PARKER (not Defrance), 1860, Quart. Jour. Geol. Soc. London, vol. 16, p. 455, pl. 20, figs. 52–56.
*Nubecularia triloculina* TEN DAM, Verh. Geol. Mijnb. Gen., vol. 15 (in press).

This species, previously known from the Albian of the Netherlands and the Middle Neocomian of England, was also found in the Glanerbrug collections. See ten Dam, 1946 above, for details.

NUBECULARIA ANTIQUA (Reuss)

*Hauerina antiqua* REUSS, 1862, Sitz. Ber. Akad. Wiss., Wien, vol. 46, p. 35, pl. 2, fig. 1.
*Trochammina frankei* EICHENBERG, 26er Jahresber. Nieders. Geol. Verh., p. 154, pl. 13, figs. 12a–d.

Test generally free, very seldom attached, more or less irregular, quite variable. Proloculum globular, followed by a short tubular chamber and several whorls of four to six chambers, more or less in an irregular spiral, sometimes partially planispiral. Chambers oval, inflated. Sutures somewhat depressed. Aperture oval, rounded, sometimes with a small collar. Wall calcareous, imperforate, rather thick, generally whitened.

*Discussion.*—Very similar to *M. triloculina* ten Dam, in its irregular form, but is distinguished by being free-living, and having whorls of four to six chambers. The specimens used by Reuss are more or less planispiral, whereas those described by Eichenberg as *Trochammina frankei* represent a more irregular type.

*Dimensions.*—Diameter 0.85 mm.

*Occurrence.*—Fairly common in the Middle Neocomian of Glanerbrug, and recorded from similar beds in Germany.

Family LAGENIDAE
Subfamily NODOSARIINAE
Genus LENTICULINA Lamarck 1804
Genotype *Lenticulina rotulata* Lamarck

LENTICULINA SUBALATA (Reuss)

*Cristellaria subalata* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 76, pl. 8, fig. 10.
*Cristellaria subalata* TEN DAM, 1946, Verh. Geol. Mijnb. Gen., vol. 15 (in press).

This species, now recorded from Glanerbrug, was previously known from the Albian of Germany, Holland and England, and the Middle Neocomian of Germany. The author's paper listed above gives detailed description and synonymy.

LENTICULINA MÜNSTERI (Roemer)

*Robulina münsteri* ROEMER, 1841, Verst. Nordd. Kreidegeb., p. 98, pl. 15, fig. 30.
*Robulina crassa* ROEMER, 1841, *idem*, p. 98, pl. 15, fig. 32.
*Cristellaria münsteri* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, p. 77, pl. 9, figs. 3, 4.
*Cristellaria rotulata* SHERLOCK (not Lamarck), 1914, Geol. Mag., Dec. 6, vol. 1, p. 263, pl. 1, fig. 25.
not *Lenticulina munsteri* Cushman 1941
not *Lenticulina munsteri* Cushman and Deaderick 1944
not *Lenticulina munsteri* Cushman 1944

This species was recorded from the Middle Necomian of Germany and England and is common at Glanerbrug. It is closely related to *L. rotulata* Lamarck but is distinguished by its fewer and less curved chambers. It is also close to *L. ordinaris* Schijfsma, 1946, which is identical with *L. munsteri* Cushman 1941, 1944, and Cushman and Deaderick 1944.

LENTICULINA ROEMERI (Reuss)

*Cristellaria roemeri* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 75, pl. 8, fig. 9.

This species is related to *L. subangulata* (Reuss) but is distinguished from that species by its more numerous chambers and central boss. Previously recorded from the

Middle Neocomian of Germany, it is fairly common in the present collections.

Genus SARACENARIA Defrance 1824
Genotype *Saracenaria italica* Defrance
SARACENARIA FRANKEI ten Dam

*Saracenaria italica* EICHENBERG (not Defrance), 1935, 26er Jarhesbei. Nieders. Geol. Ver., p. 158, pl. 11, fig. 21.
*Saracenaria frankei* TEN DAM, 1946, Jour. Paleontology, vol. 20, p. 573, pl. 88, figs. 1a, b.

This species, previously recorded from the Middle Neocomian of Germany, is fairly common in the same beds at Glanerbrug. See ten Dam for detailed description and discussion.

*Holotype.*—Geol. Stichting, Coll. no. F881.

SARACENARIA BRONNI (Roemer)

*Planularia bronni* ROEMER, 1841, Verst. Nordd. Kreideform., p. 97, pl. 15, fig. 14.
*Cristellaria bronni* REUSS, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 76, pl. 7, fig. 13.

This species has been recorded from the Middle Neocomian of Germany and England, and is fairly rare in the same formation at Glanerbrug.

Genus PLANULARIA Defrance 1824
Genotype *Planularia auris* Defrance
PLANULARIA CREPIDULARIS Roemer

*Planularia crepidularis* ROEMER, 1842, Leonh. u. Bronn's Jahrb., p. 272, fig. 3.
*Cristellaria crepidularis* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 69, pl. 7, fig. 10.
*Cristellaria tricarinella* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 68, pl. 7, fig. 9, pl. 12, figs. 2–4.
*Planularia tricarinella* EICHENBERG, 1935, 26er. Jahresber. Nieders. Geol. Ver., pp. 159, 160, pl. 13, fig. 6.
not *Cristellaria tricarinella* Paalzon 1917, 1922
not *Cristellaria tricarinella* Klähn 1921
not *Cristellaria tricarinella* Macfadyen 1935

This well-known species from the German and English Middle Neocomian is fairly common at Glanerbrug. It is quite variable. Elongate, almost circular, and all intermediate forms occur together. Surface ornamentation with dorsal keels and raised sutures is also variable, and for this reason *Cristellaria tricarinella* Reuss is considered to be a synonym.

PLANULARIA GUTTATA ten Dam

*Planularia guttata* TEN DAM, Jour. Paleontology, vol. 20, p. 574, pl. 88, figs. 2a, b.

This species, already described from the Middle Neocomian, of Glanerbrug, occurs rather commonly in the collections.

*Holotype.*—Geol. Stichting, Coll. no. F883.

Genus PSEUDOGLANDULINA Cushman 1929
Genotype *Nautilus comatus* Batsch
PSEUDOGLANDULINA HUMILIS Roemer

*Nodosaria humilis* ROEMER, 1841, Verst. Nordd. Kreidegeb., p. 95, pl. 15, no 6.
*Glandulina mutabilis* REUSS (pars), 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 58, pl. 5, figs. 9–11 (not 7, 8).
*?Nodosaria humilis* CHAPMAN, 1893, Jour. Roy. Micr. Soc., ser. 2, vol. 13, p. 585, pl. 8, fig. 18.
*Glandulina humilis* EICHENBERG, 1935, 26er Jahresber. Nieders Geol.. Ver., p. 174, pl. 16, fig. 9.

This species, recorded from the Middle Neocomian of Germany and perhaps from the Albian of England, is rather common in the Glanerbrug collections. Two kinds of initial parts are shown, probably representing microspheric and megalospheric forms. The species is closely related to *P. mutabilis* (Reuss) but is distinguished by its more conical and compact form. Some specimens described by Reuss, however, seem to be identical with the present species.

Genus VAGINULINA d'Orbigny 1826
Genotype *Nautilus legumen* Linnaeus
VAGINULINA PROTOSPHAERA Reuss
Plate 32, figure 5

*Vaginulina protosphaera* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 90, pl. 12, fig. 10.
*Vaginulina truncata* EICHENBERG (not Reuss), 1935, 26er Jahresber. Nieders. Geol. Ver., p. 179, pl. 16, fig. 5.

This species which is fairly common at Glanerbrug has already been recorded from the Middle Neocomian of German and the Albian of England. It is related to *V. kochi* Reuss.

VAGINULINA PLANA (Reuss)
Plate 32, figures 3, 4

*Cristellaria plana* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, pp. 72, 73, pl. 8, fig. 3.

This species, rare in the collections from Glanerbrug, has already been recorded from the Middle Neocomian of Germany. Reuss placed this species in the genus *Cristellaria*, but because of its curved initial part it should be referred to *Vaginulina*.

VAGINULINA SUBROTUNDA ten Dam

*Vaginulina subrotunda* TEN DAM, 1946, Jour. Paleontology, vol. 20, p. 574, pl. 88, figs. 3a, b.

This species, described by the writer in an earlier paper, is rare in the Glanerbrug collections. It is distinguished from related species by its broad and rounded base and its numerous longitudinal diverging costulae.

*Holotype.*—Geol. Stichting Coll. no. F809.

VAGINULINA NEOCOMIANA Chapman
Plate 32, figure 14

*Vaginulina neocomiana* CHAPMAN, 1894, Jour. Geol. Soc. London, vol. 50, p. 711, pl. 34, figs. 10–11.
*?Vagulina debilis* EICHENBERG 1935 (not Berthelin), 26er Jahresber. Nieders. Geol. Ver., p. 167, pl. 12, fig. 9.

This species is closely related to *V. debilis* Berthelin, but is distinguished by its less pointed basal portion and being about twice as large. The specimens described by Eichenberg as *V. debilis* are not identical with those of Berthelin, because of their much greater size, but seem closely related to or conspecific with *V. neocomiana* Chapman. In addition to the present specimens from the Middle Neocomian at Glanerbrug, it has been recorded from the Middle Neocomian of England and probably from the same formation in Germany.

VAGINULINA KOCHII STRIOLATA Reuss

*Vaginulina striolata* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 46, pl. 3, fig. 7.

For detailed description, synonymy and discussion of this species see Cushman and Alexander (1930 and Tappan (1940). It is recorded from the Albian of Europe and America, whereas our specimens are from the Middle Neocomian of Glanerbrug.

Genus VAGINULINOPSIS Silvestri 1904
Genotype *Vaginulinopsis carinata* Silvestri

VAGINULINOPSIS RETICULOSA ten Dam

*Vaginulinopsis reticulosa*, 1946, TEN DAM, Jour. Paleontology, vol. 20, p. 574, pl. 88, figs. 4a, b.

Fairly rare in the Middle Neocomian at Glanerbrug.

*Holotype.*—Geol. Stichting Coll. no. F810.

VAGINULINOPSIS PACHYNOTA ten Dam

*Vaginulinopsis pachynota* TEN DAM, 1946, Jour. Paleontology, vol. 20, p. 575, pl. 88, figs. 5, 6a, b.

Rather common in the Middle Neocomian at Glanerbrug.

*Holotype.*—Geol. Stichting Coll. no. F811.

Genus NODOSARIA Lamarck 1812
Genotype *Nautilus radicula* Linnaeus

NODOSARIA SCEPTRUM Reuss

*Nodosaria sceptrum* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 37, pl. 2, fig. 3.
*Nodosaria sceptrum*, CHAPMAN, 1893, Jour. Roy. Micr. Soc., ser. 2, vol. 13, p. 592, pl. 9, fig. 9.
*Nodosaria sceptrum* EICHENBERG, 1933, 25er Jahresber. Nieders. Geol. Ver., p. 180, pl. 19, fig. 1.
not *Nodosaria sceptrum* Franke 1928.

This species is related to *N. tubifera* Reuss but is distinguished by its finer sutures and the more or less angular based chambers. The specimens described by Franke as *N. sceptrum* from the Upper Cretaceous are identical with *N. tubifera* Reuss. The present species is recorded from the Albian of Holland and England, from the Barremian and Middle Neocomian of Germany, and the Middle Neocomian of Glanerbrug.

NODOSARIA OBSCURA Reuss

*Nodosaria obscura* REUSS, 1845, Verst. Böhm. Kreideform., vol. 1, p. 26, pl. 13, figs. 7–9.

For detailed description, synonymy and discussion see Brotzen (1936, pp. 84–88). Fairly rare in the Middle Neocomian at Glanerbrug, it has previously been recorded from the Lower and Upper Cretaceous of America and Europe.

NODOSARIA TUBIFERA Reuss

*Nodosaria tubifera* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 37, pl. 2, fig. 4.
*Nodosaria tubifera* CHAPMAN, 1893, Jour. Roy. Micr. Soc., ser. 2, vol. 13, p. 592, pl. 9, fig. 11.
*Nodosaria tubifera* FRANKE, 1928 (not Reuss), Preuss., Geol. Landes. Abh. vol. 111, p. 46, pl. 4, fig. 1.
*Nodosaria tubifera* EICHENBERG, 1935, 25er Jahresber. Nieders. Geol. Ver., p. 179, pl. 18, fig. 2.

This species is closely related to *N. sceptrum* Reuss, but is distinguished by its smaller dimensions, less inflated chambers and more numerous costulae. It is recorded

from the Upper Cretaceous of Germany, the Albian of England, Germany and Holland, and the Middle Neocomian of Glanerbrug.

NODOSARIA LOEBLICHAE ten Dam, new name

*Dentalia* sp. (?n. sp.) EICHENBERG, 1935, 26er Jahresber. Ber. Nieders. Geol. Ver., p. 166, pl. 12, fig. 3.
*Nodosaria* sp. EICHENBERG, 1935, *ibid.*, p. 172, pl. 12, fig. 4.
*Nodosaria rugosa* TEN DAM, 1946, Jour. Paleontology, vol. 20, p. 575, pl. 88, fig. 7.

A few specimens of this species, already described in 1946 by the author, were found in the collections from Glanerbrug. Eichenberg described two forms from the Middle Neocomian of Germany which seem to be identical with our species.

Mr. Hans Thalmann has brought to my attention the fact that the name I proposed for this species is preoccupied. I take pleasure therefore in renaming it for Mrs. Loeblich who has done excellent work on the Lower Cretaceous Foraminifera of Texas and Oklahoma

*Holotype.*—Geol. Stichting, Coll. no. F841.

GENUS DENTALINA d'Orbigny 1826
Genotype *Dentalina obliqua* d'Orbigny

DENTALINA INEPTA Reuss

*Dentalina inepta* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, pp. 40, 41, pl. 2, fig. 13.

This species is related to certain species of Nodosaria, for example *N. obscura* Reuss, but is distinguished by its last chamber which is drawn out to an eccentric point. It was recorded by Reuss from the Middle Neocomian of Germany, and is rather rare at Glanerbrug.

DENTALINA SERRATA Eichenberg

*Dentalina serrata* EICHENBERG, 1935, 26er Jahresber. Nieders. Geol. Ver., p. 167, pl. 12, fig. 7a, b.

This species is recorded from the Middle Neocomian of Germany, and is rather rare in the same formation at Glanerbrug. It is distinguished from related species by its serrate ventral side.

DENTALINA HILSEANA Reuss

*Dentalina hilseana* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 41, pl. 2, fig. 14.

This species is closely related to *D. distincta* Reuss, but differs in its more compact chambers, only slightly oblique sutures, and central oblique spine. Our specimens from the Middle Neocomian of Glanerbrug are somewhat larger than those described by Reuss from the same formation of Germany.

Genus QUADRATINA ten Dam 1946
Genotype *Quadratina depressula* ten Dam

QUADRATINA DEPRESSULA ten Dam

*Quadratina depressula* TEN DAM, 1946, Jour. Paleontology, vol. 20, p. 575, pl. 88, fig. 8a, b.
*Quadratina depressula* TEN DAM, Soc. Geol. France, ser. 5, vol. 16 (in press).

This species is known only from the Middle Neocomian of Glanerbrug.

*Holotype.*—Geol. Stichting, Coll. No. F851.

Genus TRISTIX Macfadyen 1941
Genotype *Tristix liasinum* (Berthelin)

TRISTIX ACUTANGULUM (Reuss)
Plate 32, figures 9, 10

*Rhabdogonium acutangulum* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 55, pl. 4, fig. 14.
*?Rhabdogonium tricarinatum acutangulum* CHAPMAN, Jour. Roy. Micr. Soc., ser. 2, vol. 14, p. 159, pl. 4, fig. 8.

This species is distinguished by its only slightly concave sides, gently curved sutures, inflated chambers, and slender form. It is probably identical with specimens found by the author in the Albian of Holland, which are, however, smaller than the original form. The specimens described by Chapman show the chambers enlarging more rapidly than in the original form, but they also are probably identical with these species. It is known from the Albian of Holland and England and the Middle Neocomian of Germany and Glanerbrug.

TRISTIX ACUTANGULUM LAMELLOSUM ten Dam

*Rhabdogonium tricarinatum* BURROWS, SHERBORN, and BAILEY, 1890, (not d'Orbigny), Jour. Roy. Micr. Soc., ser. 2, vol. 10, p. 558, pl. 10, fig. 7.
*Tristix acutangulum lamellosa* TEN DAM, 1946, Jour. Paleontology, vol. 20, p. 575, pl. 88, fig. 9.

A few specimens of this species were found at Glanerbrug. Its previous record is under another name from the Middle Neocomian of England.

*Holotype.*—Geol. Stichting, Coll. no. F833.

TRISTIX CRASSUM ten Dam

*Tristix crassum* TEN DAM, 1946, Jour. Paleontology, vol. 20, p. 576, pl. 88, figs. 10a–c.

This species is known only from the Middle Neocomian at Glanerbrug.

*Holotype.*—Geol. Stichting. Coll. no. F813.

TRISTIX cf. EXCAVATUM Reuss
Text figure 2

A few specimens of a species of *Tristix* were found at Glanerbrug which are very

FIG. 2. *Tristix* cf. *excavatum* (Reuss) Plesiotype no. A642.

closely related to *T. excavatum* Reuss but differ in their less concave sides and less sharp edges.

*Typoid.*—ten Dam Coll. No. A642.

TRISTIX INSIGNE Reuss
Plate 32, figures 11, 12

*Rhabdogonium insigne* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 56, pl. 5, fig. 2.
*Rhabdogonium insigne* SHERLOCK, 1914, Geol. Mag., Dec. 6, vol. 1, pp. 258, 259, pl. 18, fig. 21.
*Rhabdogonium insigne* EICHENBERG, 1935, 26er Jarhesber. Nieders. Geol. Ver., p. 181, pl. 14, fig. 4.

This species, which is related to *T. tristix* ten Dam, is characterized by its rounded base and large initial chamber. Known from the Middle Neocomian of England and Germany, it is rare at Glanerbrug.

Genus FRONDICULARIA Defrance 1826
Genotype *Frondicularia complanata* Defrance

FRONDICULARIA CONCINNA Koch

*Frondicularia concinna* KOCH, 1846, Paleontographica, vol. 1, art. 1, p. 172, pl. 24, fig. 5.
*Frondicularia concinna* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, pp. 54, 55, pl. 4, fig. 13.
*Frondicularia quadrata* CHAPMAN, 1894, Jour. Roy. Micr. Soc., ser. 2, vol. 14, p. 158, pl. 4, fig. 4.
*Frondicularia concinna* EICHENBERG, 1933, 25er Jahresber. Nieders. Gel. Ver., p. 78, pl. 4, fig. 1.

This form differs from related species in its ornamentation with longitudinal, interrupted ridges, and its rounded rectangular section with narrow peripheral keel. It is identical with *F. quadrata* Chapman which represents only a larger, aberrant form. The specimens from the Middle Neocomian are generally more rhombic than those from the Albian. Known from the Middle Neocomian of Germany and Holland (Glanerbrug), and from the Albian of Holland, Germany, and England.

FRONDICULARIA SIMPLICISSIMA ten Dam

*Frondicularia simplicissima* TEN DAM, 1946, Jour. Paleontology, vol. 20, p. 576, pl. 88, figs. 11a, b.

A few specimens of this species were found in the present collections. See ten Dam (1946) for discussion and description.

*Holotype.*—Geol. Stichting, Coll. no. F882.

FRONDICULARIA ANGUSTISSIMA Reuss

*Frondicularia angustissima* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien.

Some specimens of a *Frondicularia* were found in the Middle Neocomian at Glanerbrug which resemble *F. angustissima* Reuss but differ in having their chambers inclined toward the initial end and less pronounced ornamentation. This species was originally described from the Upper Senonian of Germany.

FRONDICULARIA HASTATA Roemer

*Frondculariia hastata* ROEMER, 1842, Leonhard and Bronn's Jahrb., p. 272, pl. 7b, fig. 5.
*Frondicularia hastata* REUSS, 1862, Sitz. Ber. Wiss. Wien, vol. 46, p. 53, pl. 4, fig. 10.

This species is known from the Middle Neocomian of Germany and Glanerbrug. It is distinguished from others by its lack of ornamentation other than the median ridge in the initial portion.

Genus CITHARINA d'Orbigny 1839
Genotype *Vaginulina striatula* d'Orbigny

CITHARINA ACUMINATA (Reuss)

*Vaginulina acuminata* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 49, pl. 4, fig. 1.
not *Vaginulina acuminata* Eichenberg 1935

This species is recorded from the Middle Neocomian of Germany and Glanerbrug. It is distinguished by being broadest at about midlength.

CITHARINA RETICULATA (Cornuel)

*Planularia reticulata* CORNUEL, 1848, Mem. Soc. Geol. France, ser. 2, vol. 3, pt. 1, p. 253, pl. 2, figs. 1–4.

This species is somewhat similar to *Vaginulina cristellaroides* Reuss in its reticulate ornamentation, but the structure of the chambers is different, and its dorsal periphery is truncate. It is rather rare but present in all samples from the Middle Neocomian at Glanerbrug. Its only other recorded occurrence is in the Ostrea-clay of Wassy, France, probably also Middle Neocomian.

CITHARINA HARPA (Roemer)

*Vaginulina harpa* ROEMER, 1841, Verst. Nordd. Kreidegeb., p. 96, pl. 15, fig. 12.
*Vaginulina dunkeri* KOCH, 1848, Palaeontografica vol. 1, pt. 4, p. 172, pl. 24, fig. 3.
*Vaginulina harpa* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 51, pl. 4, figs. 5–7.
*Vaginulina harpa* EICHENBERG, 1935, 26er Jahresber. Nieders. Geol. Ver., p. 177, pl. 14, fig. 7.
not *Citharina harpa* Klahn 1921
*Citharina harpa* Macfadyen 1935
*Citharina harpa* Fagginder Auer 1938

This species is rather variable but is distinguished from others by its sharp longitudinal raised ridges making the chamber structure and sutures almost invisible. It is related to *C. incrassata* (Reuss), but the latter is much thicker. Specimens from the Jurassic referred to this species are misidentified.

Common in the Middle Neocomian at Glanerbrug, and there are several occurrences recorded from the Middle Neocomian of Germany.

CITHARINA INTUMESCENS (Reuss)

*Vaginulina intumescens* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 49, pl. 4, fig. 2.
*Vaginulina intumescens* CUSHMAN, 1930, Contr. Cush. Lab. Foram. Res., vol. 6, pt. 1, p. 5, pl. 2, figs. 1–6.

The general form of this species resembles *C. gracilina* Marie, but it differs by its ornamentation of raised longitudinal ridges of variable thickness. It is known from the Albian of Texas and the Middle Neocomian of Germany and Glanerbrug.

CITHARINA INCRASSATA (Reuss)

*Vaginulina incrassata* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 52, pl. 4, fig. 9.

This species is characterized by its stout initial part and its sharp raised longitudinal ridges. It is recorded from the Middle Neocomian of Germany and Glanerbrug.

CITHARINA DISCORS (Koch)

*Vaginulina discors*, KOCH, 1848, Palaeontografica, vol. 1, pt. 4, p. 172, pl. 34, figs. 1, 2.
*Vaginulina discors* REUSS, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 50, pl. 3, figs. 10–12.
not *Vaginulina discors* Chapman 1894
*Citharina discors* Marie 1938

This species is closely related to specimens described by Chapman and Marie as *Vaginulina* and *Citharina discors*, but differs by its lack of a dorsal keel, its oval proloculus, and smaller size. Common at Glanerbrug and also recorded from the Middle Neocomian of Germany.

Genus LINGULINA d'Orbigny 1826
Genotype *Lingulina carinata* d'Orbigny

LINGULINA NODOSARIA Reuss

*Lingulina nodosaria* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 59, pl. 5, fig. 12.

For detailed synonymy, description and discussion, see Tappan 1940, p. 107. Occurs at numerous places in the Albian of Germany, England, and Texas, probably in the Cenomanian of Bavaria and in the Middle Neocomian of Germany and Glanerbrug.

LINGULINA PRAELONGA ten Dam

*Frondicularia loreyi* EICHENBERG, 1935 (not Berthelin), 26er Jahresber. Nieders. Geol. Ver., p. 179, pl. 11, fig. 1.
*Lingulina praelonga* TEN DAM, 1946, Jour. Paleontology, vol. 20, p. 576, pl. 88, figs. 12a, b.

A few specimens were found in Glanerbrug material, and Eichenberg recorded the same species under another name from the Middle Neocomian of Germany.

Genus MARGINULINOPSIS Silvestri 1904
Genotype *Vaginulina soluta carinata* Silvestri

MARGINULINOPSIS COMMA Roemer
Plate 32, figures 1, 2

*Marginulina comma* ROEMER, 1841, Verst. Nordd. Kreideform., p. 96, pl. 15, fig. 15.

Test free-living, more or less compact, rounded in section. Dorsal side broadly

rounded. Initial chamber globular, followed by four small chambers planispirally coiled, and three or four uniserial chambers, distinct, slightly inflated, wider than high. Sutures even with surface, limbate in coiled portion, slightly depressed in uniserial part. Aperture terminal, excentric, dorsal, radiate.

*Dimensions.*—Length 0.88 mm., width 0.43 mm. The species resembles *M. bronni* in its general form.

This species is recorded by Roemer from the Middle Neocomian of Germany and is rare in the Glanerbrug material.

MARGINULINOPSIS GRACILLISSIMA (Reuss)
Plate 32, figures 7, 8

*Cristellaria gracilissima* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 64, pl. 6, figs. 9, 10.
*Cristellaria gracillissima* SHERLOCK, 1914, Geol. Mag., Dec. 6, vol. 1, p. 260, pl. 18, fig. 26.
*Cristellaria gracillissima* EICHENBERG, 1933, 25er Jahresber. Nieders. Geol. Ver., p. 175, pl. 11, fig. 8.

Specimens are generally larger than those described by Reuss and Eichenberg. This species is recorded from the Barremian of Germany and from the Middle Neocomian of Germany, England, and Glanerbrug.

Genus MARGINULINA d'Orbigny 1826
Genotype *Marginulina glabra* d'Orbigny

MARGINULINA JONESI Reuss

*Marginulina jonesi* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien., vol. 46, p. 61, pl. 5, fig. 19.
*Marginulina jonesi* CHAPMAN, 1894, Jour. Roy. Micr. Soc., ser. 2, vol. 14, p. 163, pl. 4, fig. 24.
*Marginulina munieri* CHAPMAN, 1894 (not Berthelin), *idem*, p. 163, pl. 4, fig. 22.
*Marginulina jonesi* CHAPMAN, 1899, Ann. Mag. Nat. Hist., ser. 7, vol. 3, 306.
*Marginulina jonesi* EICHENBERG, 1935, 26er Jahresber. Nieders.
not *Marginulina jonesi* Cushman and Church, 1920.

This species is closely related to *M. robusta* Reuss, which is, however, more compact and has six longitudinal ridges compared with the ten or more of the present species. It is not the same as *M. munieri* Berthelin, but the specimens described by Chapman as *M. munieri* seem to represent a young stage of *M. jonesi*. Specimens from the Middle Neocomian of Glanerbrug are generally smaller than those from the Albian. This species is rather common in the Albian of Europe and has been recognized from the Middle Neocomian of England and Germany.

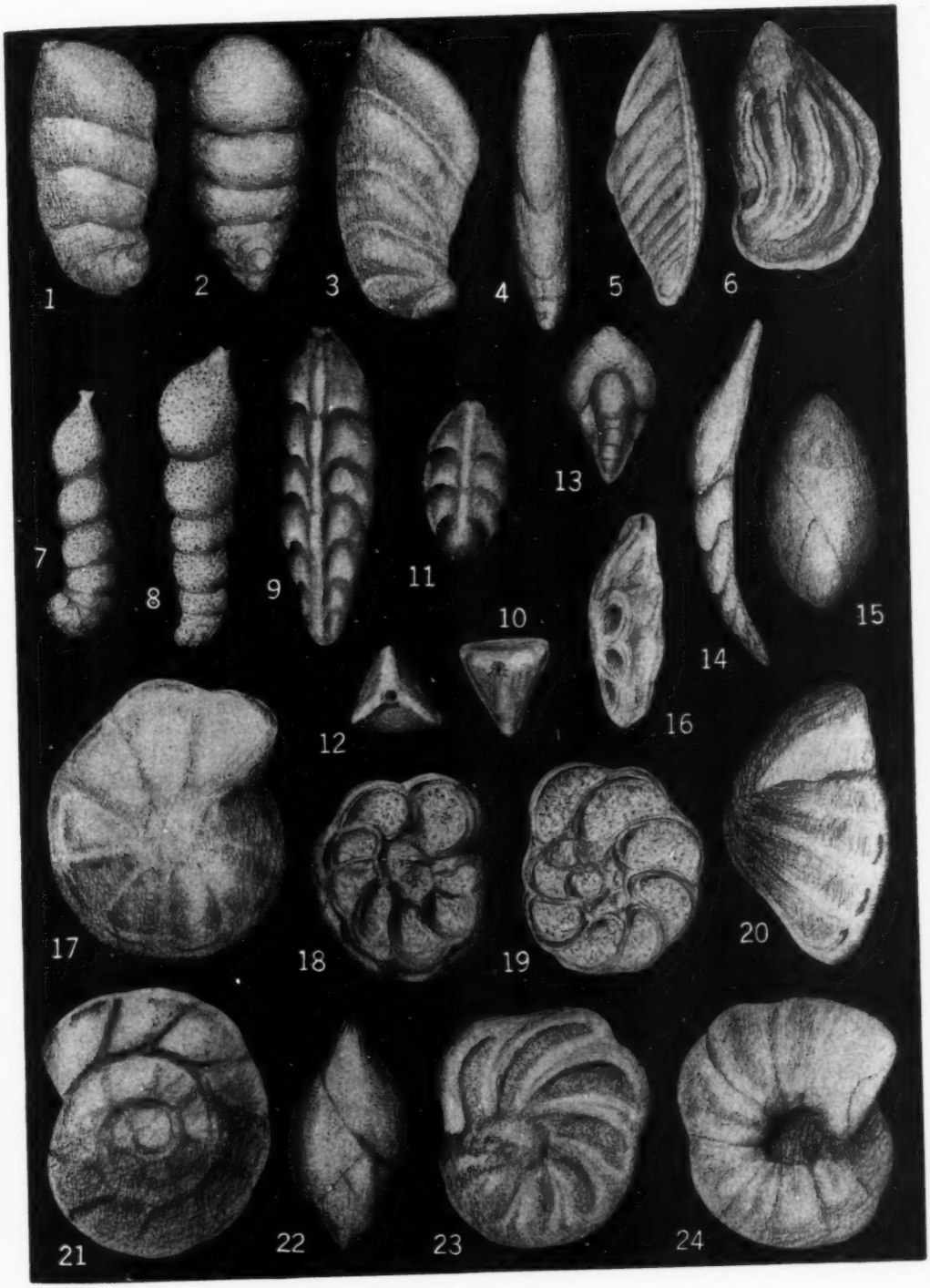
MARGINULINA HECHTI ten Dam

*Marginulina linearis* EICHENBERG, 1933 (not Reuss), 25er Jahresber. Nieders. Geol. Ver., p. 161, pl. 11, figs. 2, 7.
*Marginulina hechti* TEN DAM, 1946, Jour. Paleontology, vol. 20, p. 576, pl. 88, figs. 13, 14.

A few specimens of this species were found in the Middle Neocomian of Glanerbrug. Eichenberg described a similar species as *M. linearis* from the Barremian of Germany

EXPLANATION OF PLATE 32

FIGS. *1, 2—Marginulopsis comma* (Roemer), side and front views, ×45. Hypotype A656. (p. 183)
*3, 4—Vaginulina plana* (Reuss), side and front views, ×80. Hypotype A625. (p. 179)
*5—Vaginulina protosphaera* (Reuss), ×15. Hypotype A624. (p. 179)
*6—Marginulina robusta* Reuss, ×95. Hypotype A722. (p. 185)
*7, 8—Marginulinopsis gracillissima* (Reuss), ×45. *7*, Hypotype A657a, *8*, hypotype A657b. (p. 184)
*9, 10—Tristix acutangulum* (Reuss), side and apertural views, ×65. Hypotype A639. (p. 181)
*11, 12—Tristix insigne* (Reuss), side and apertural views, ×75. Hypotype A643. (p. 182)
*13—Quadrulina rhabdogonoides* (Chapman), ×60. Hypotype A666. (p. 185)
*14—Vaginulina neocomiana* (Chapman), ×60. Hypotype A627. (p. 180)
*15—Globulina prisca* Reuss, ×70. Hypotype A667. (p. 185)
*16, 18, 19—Epistomina ornata* (Roemer), ×55. Ventral, dorsal, and edge views of hypotype A677. (p. 188)
*17, 20, 21—Epistomina caracolla* (Roemer), ×40. Ventral, dorsal and edge views of hypotype A676. (p. 187)
*22—Pseudopolymorphina eichenbergi* ten Dam, ×65. Holotype F825. (p. 186)
*23, 24—Anomalina sigmoicosta* ten Dam, ×90. Ventral and dorsal views of the holotype, A679. (p. 189)




ten DAM, Neocomian Foraminifera

MARGINULINA ACUTICOSTA Reuss

*Marginulina acuticosta* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, pp. 62, 63, pl. 6, fig. 3.

This species is closely related to *M. jonesi* Reuss, and *M. robusta* Reuss, but differs in having eight to 11 sharp ridges, and is more slender. It was recorded by Reuss from the Albian of Germany, and is present in the Middle Neocomian of Glanerbrug.

MARGINULINA FOEDA (Reuss)

*Cristellaria foeda* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 64, pl. 6, figs. 11–13.
*??Marginulina foeda* EICHENBERG, 1933, 25er Jahresber. Nieders. Geol. Ver., p. 8, pl. 5, fig. 6.

This species is characterized by its ornamentation with numerous sharp spines. Perhaps the specimens described by Eichenberg (1933) are different because of their fewer chambers and less dense ornamentation. Probably they should be considered a variety of this species. *M. foeda* was recorded by Reuss from the Middle Neocomian of Germany and it also occurs at Glanerbrug. Eichenberg's specimens came from the Albian of Germany.

MARGINULINA ROBUSTA Reuss
Plate 32, figure 6

*Marginulina robusta* REUSS, 1862, Sitz. Ber, Akad. Wiss. Wien, vol. 46, p. 63, pl. 6, figs. 5. 6.

Several specimens of this species were found in the Middle Neocomian of Glanerbrug, but they are smaller than those described by Reuss. This species from the Middle Neocomian of Germany is closely related to *M. jonesi* Reuss but differs in its more compact form and smaller number of costae.

Subfamily LAGENINAE
Genus LAGENA Walker and Jacob 1798
Genotype *Lagena sulcata* Walker and Jacobs
LAGENA APICULATA (Reuss)

*Oolina apiculata* REUSS, 1850, Haid. Naturw. Abh., vol. 4, p. 22, pl. 1, fig. 1.

For detailed description and synonyms see Tappan, 1940. The species has been described from numerous formations in the Cretaceous and Tertiary. It is recorded from the Albian of Europe and America. Specimens are fairly common in the Middle Neocomian of Glanerbrug.

LAGENA cf. HISPIDA Reuss

From the Middle Neocomian of Glanerbrug. Some specimens of *Lagena* resemble *L. hispida* Reuss, but differ in having a basal spine. Franke, 1929, and Marie, 1940, recorded similar specimens with a basal spine.

LAGENA ACUTICOSTA Reuss

*Lagena acuticosta* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 303, pl. 1, fig. 4.

A few specimens of this well-known species, recorded from numerous deposits, fossil and recent, were found in the Middle Neocomian of Glanerbrug.

Family POLYMORPHINIDAE
Subfamily POLYMORPHININAE
Genus QUADRULINA Cushman and Ozawa 1930
Genotype *Polymorphina rhabdogonoides* Chapman
QUADRULINA RHABDOGONOIDES (Chapman)
Plate 32, figure 13

*Polymorphina rhabdogonoides* CHAPMAN, 1894, Quart. Jour. Geol. Soc. London, vol. 10, p. 716, pl. 34, fig. 12.
*Quadrulina rhabdogonoides* CUSHMAN and OZAWA, 1930, Proc. U. S. Nat. Mus., vol. 77, art. 6, p. 18, pl. 1, fig. 4.

This species, well described by Cushman and Ozawa, is closely related to *Q. frondiculariodes* (Chapman) but differs in having a distinctly quadrangular section. It is rare in the Middle Neocomian of Glanerbrug and has been recorded by Chapman from the Middle Neocomian of England.

Genus GLOBULINA d'Orbigny 1826
Genotype *Globulina gibba* d'Orbigny
GLOBULINA PRISCA Reuss
Plate 32, figure 15

*Globulina prisca* REUSS, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 79, pl. 9, fig. 8.
*?Polymorphina acuta* OLSZEWSKI, 1875, Sprawozd. Kom. Fiz. Ak. Umiej. Krakowie, vol. 9, p. 120, pl. 1, fig. 13.
*Polymorphina fusiformis* CHAPMAN, 1896 (not

Reuss), Jour. Roy. Micr. Soc., ser. 2, vol. 16, p. 11, pl. 2, fig. 9 (not fig. 10).
*Globulina prisca* CUSHMAN and OZAWA, 1930, Proc. U. S. Nat. Mus., vol. 77, art. 6, p. 73, pl. 12, fig. 6.

This species is closely related to *G. minuta* (Roemer) but differs in having an oval section. It is recorded from the Lower Cretaceous of Europe, Upper Cretaceous of Europe and America, and is common in the Glanerbrug Middle Neocomian.

Genus PSEUDOPOLYMORPHINA Cushman and Ozawa 1928
Genotype *Pseudopolymorphina hanzawai* Cushman and Ozawa
PSEUDOPOLYMORPHINA EICHENBERGI ten Dam, new species
Plate 32, figure 22

*Polymorphina* aff. *porrecta* EICHENBERG (not Reuss), 1935, 26er Jahresber. Nieders. Geol. Ber., pp. 183, 184, pl. 17, figs. 4a, b.

Test free, rounded at base, last three chambers forming ⅔ of test, oval in section, width about half the length. Initial stage pentaserial, adult biserial. Chambers longer than broad, adult more or less inflated. Last chamber more inflated than preceding ones. Sutures finely limbate, slightly depressed. Aperture terminal, radiate. Wall finely perforate, calcareous; surface smooth.

*Discussion.*—Closely allied to *P. leopolitana* (Reuss) but differs by being twice as long as broad instead of three times, and being more compact. The specimens described by Eichenberg bear no resemblance to *Polymorphina porrecta* Reuss, which is much more slender and acuminate at both ends.

*Dimensions.*—Length, 0.55 mm.; width, 0.275 mm.

*Occurrence.*—Fairly common in the Middle Neocomian of Glanerbrug, and known also from the Middle Neocomian of Germany.

*Holotype.*—Geol. Stichting, Coll. no. F-825.

Genus EOGUTTULINA Cushman and Ozawa 1930
Genotype *Eoguttulina anglica* Cushman and Ozawa
EOGUTTULINA ANGLICA Cushman and Ozawa

*Eoguttulina anglica* CUSHMAN and OZAWA, 1930, Proc. U. S. Nat. Mus., vol. 77, art. 6, p. 16, pl. 1, figs. 3a–c.

For detailed description, discussion and synonymy see ten Dam (Verh. Geol. Mijn. Gen., vol. 15, 1946). A few examples of this species were found in the Middle Neocomian of Glanerburg, and it was previously known from the Albian of Holland and England.

Subfamily RAMULINAE
Genus BULLOPORA Quenstedt 1856
Genotype *Bullopora rostrata* Quenstedt
BULLOPORA LAEVIS (Sollas)

*Webbina laevis* SOLLAS, 1877, Geol. Mag., dec. 2, vol. 4, pp. 103, 104, pl. 6, figs. 1–3.

For detailed description, discussion and synonymy see ten Dam, Verh. Geol. Mijnb., vol. 15, 1946.

Genus RAMULINA Rupert Jones 1875
Genotype *Ramulina laevis* Rupert Jones
RAMULINA ACULEATA Wright

*Ramulina aculeata* WRIGHT, 1886, Proc. Belfast Nat. Field Club, App. 9, p. 331, pl. 27, fig. 11.

This well-known species, recorded from Cretaceous and Tertiary deposits of Europe and America, is represented by several specimens from the Glanerbrug Middle Neocomian beds.

Family ROTALIDAE
Subfamily SPIRILLININAE
Genus SPIRILLINA Ehrenberg 1843
Genotype *Spirillina vivipara* Ehrenberg
SPIRILLINA MINIMA Schacko

*Spirillina minima* SCHACKO, 1892, Arch. für Naturgesch. Medklen., p. 159, pl. 1, fig. 4.

For detailed information on this species see Tappan, 1940. A few specimens were found of this species at Glanerbrug, and it has previously been recorded from the Lower and Upper Cretaceous of Europe and from the Albian of Texas.

Subfamily DISCORBINAE
Genus PATELLINA Williamson 1858
Genotype *Patellina corrugata* Williamson
PATELLINA SUBCRETACEA Cushman and Alexander

*?Patellina corrugata* CHAPMAN, 1894, (not Williamson), Jour. Roy. Micr. Soc., ser. 2, vol. 14, p. 718.
*Patellina subcretacea* CUSHMAN and ALEXANDER,

1930, Contr. Cush. Lab. Foram. Res., vol. 6, p. 10, pl. 3, fig. 1.
*Patellina subcretacea* Lozo, 1944, Am. Midland Nat., vol. 31, no. 3, p. 561, pl. 4, fig. 8.

A few specimens of this form were found at Glanerbrug. It is also known from the Albian of Texas and the Netherlands, and perhaps from the Albian of England.

Family Ceratobuliminidae
Genus Lamarckina Berthelin 1881
Genotype *Pulvinulina erinacea* Karrer
Lamarckina lamplughi (Sherlock)
Text figures 3a-c

*Discorbina turbo* Chapman, 1896, (not d'Orbigny) Jour. Roy. Micr. Soc., ser. 2, vol. 16, p. 591, pl. 13, fig. 13.
*Pulvinulina lamplughi* Sherlock, 1914, Geol. Mag., dec. 6, vol. 1, p. 290, pl. 19, fig. 16.
*Discorbis turbo* Eichenberg (not d'Orbigny), 1935, 25er Jahresber. Nieders, Geol. Ver., p. 20, pl. 1, fig. 11.
*Lamarckina lamplughi* ten Dam, Bull. Soc. Géol. France, ser. 2, vol. 16, p. 111, fig. 6a–c.

Test small, more or less biconvex, with deep umbilicus. Periphery acute slightly lobulate. Umbilical side slightly convex, composed of 5 chambers, the last forming about one-third of the test. Chambers triangular, last two or three inflated. Sutures gently curved, tangential, limbate, flush with surface, or slightly raised. Aperture of last chamber a narrow slit in umbilicus, with short radial prolongation. In broken specimens one can observe an internal subdivision at the base of the septal face with an internal aperture above. Surface smooth.

*Dimensions.*—Diameter, 0.32 mm., thickness, 0.15 mm.

*Discussion.*—This species is characterized by its curved chambers, tangential sutures, and its aperture. It is related to *L. ripleyensis* Cushman, but differs in its partially radial apertural slit, which is much less developed in that species.

*Occurrence.*—Recorded from the Middle Neocomian of England and rare in the same formation at Glanerbrug, and from the Albian of England, Holland, and Germany.

Lamarckina nitens (Reuss)

*Rosalina nitens* Reuss, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, pp. 86, 87, pl. 11, fig. 4.

The Glanerbrug specimens correspond exactly with the description and figures of Reuss. The apertural characters suggest the genus *Lamarckina* although the small number of specimens do not permit observation of the internal subdivision. This species differs from others from the Lower Cretaceous in its very small size (0.2 mm.), planoconvex test, last coil with four chambers and very short radial apertural slit. It was described from the Middle Neocomian of Germany and is found in some samples from the same formation of Glanerbrug.

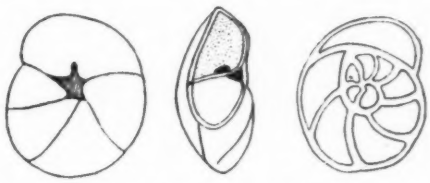


Fig. 3. *Lamarckina lamplughi* (Sherlock). Plesiotype no. A674.

Genus Epistomina Terquem 1883
Genotype *Epistomina regularis* Terquem
Epistomina caracolla (Roemer)
Plate 32, figures 17, 20, 21

*Gyroidina caracolla* Roemer, 1841, Verst. Nordd. Kreideform., p. 97, pl. 15, fig. 22.
*Rotalia caracolla* Reuss, 1862, Sitz. Ber. Akad. Wiss. Wien, vol. 46, p. 84, pl. 10, fig. 6.
*Pulvinulina caracolla* Sherlock, 1914, Geol. Mag., dec. 6, vol. 1, p. 289, pl. 19, fig. 15.
*Epistomina caracolla* Eichenberg, 1935, 26er Jahresber. Nieders. Geol. Verh., p. 185, pl. 13, fig. 8.
not *Pulvinulina caracolla* Chapman 1898
*Epistomina caracolla* Franke 1925
*Epistomina caracolla* Cushman and Church 1920

Test free, stout, strongly biconvex, with keeled limbate periphery. Dorsal side less convex than umbilical. Spire trochoid, composed of two and one half to three coils, the last with 11 chambers. Chambers more or less curved, formed like a parallelogram. Sutures thick, limbate raised, almost straight. Central portion more or less indistinct because of presence of a central boss of clear shell material. Aperture in plane of coiling, a narrow slit near the periphery with limbate border. In broken specimens one can observe the internal subdivisions with internal apertures. Surface smooth.

*Dimensions.*—Diameter, 1.0 mm.; thickness 0.55 mm.

*Occurrence.*—Common at Glanerbrug and also recorded with certainty from the Middle Neocomian of England and Germany. Insofar as may be determined from the descriptions and figures, records of this species from beds other than the Lower Cretaceous are based on misidentifications.

*Discussion.*—This species is related to *E. chapmani* ten Dam 1946, but distinguished by its stout test and raised sutures. *E. chapmani* is identical with the specimens described by Chapman as *E. caracolla.* Most specimens are highly pyritized. Some are larger than the one figured.

EPISTOMINA ORNATA (Roemer)
Plate 32, figures 16, 18, 19

*Truncatulina ornata* ROEMER, 1841, Verst. Nordd. Kreidegeb., p. 98, pl. 15, fig. 25.
not *Epistomina ornata* Terquem 1885
" " Macfadyen 1935

Test free, small circular, biconvex, with slightly acute periphery. Spire trochoid, composed of one and a half to two coils of seven or eight chambers. Chambers of dorsal side gently curved, somewhat higher than broad, slightly depressed. Sutures thickened, limbate, raised, curved. Chambers of initial coil hardly visible because of thickened sutures. Chambers on umbilical side depressed, more or less pentagonal. Central portion with an irregular callus. Sutures more or less thickened, limbate, raised. Aperture at periphery, parallel to plane of coiling, with limbate and raised rim, giving pentagonal aspect to chambers. Internal structure invisible, due to pyritization of the test.

*Dimensions.*—Diameter, 0.6 mm.; thickness, 0.4 mm.

*Discussion.*—This species resembles *E. spinulifera* Reuss, and *E. reticulata suturalis* ten Dam from the Albian, but differs from the first by its small size, less raised sutures and lesser ornamentation, and from the second in having fewer chambers, thicker sutures, and pentagonal chambers on the umbilical side. *E. charlottae* Vieaux and *E. limbata* Tappan from the Albian of Texas and Oklahoma have strongly raised sutures but otherwise they are quite different from this species.

*Occurrence.*—Fairly rare in the Middle Neocomian of Glanerbrug, and recorded by Roemer from the same formation in Germany. Specimens from the Jurassic, described by Terquem and Macfadyen as *E. ornata* are misidentified.

Family GLOBIGERINIDAE
Subfamily GLOBIGERININAE
Genus GLOBIGERINA d'Orbigny 1826
Genotype *Globigerina bulloides* d'Orbigny

GLOBIGERINA INFRACRETACEA Glaessner

*Globigerina cretacea* BURROWS, SHERBORN, and BAILEY, 1890, (not d'Orbigny), Jour. Roy. Micr. Soc., ser. 2, vol. 10, p. 561, pl. 11, fig. 18.
*Globigerina cretacea* CHAPMAN, 1892, (not d'Orbigny), Quart. Jour. Geol. Soc., vol. 48, p. 517, pl. 15, fig. 13.
*Globigerina cretacea* CHAPMAN, 1896, (not d'Orbigny), Jour. Roy. Micr. Soc., ser. 2, vol. 16, p. 588, pl. 13, figs. 5, 6.
*Globigerina bulloides* CHAPMAN, 1896, (not d'Orbigny), *idem*, p. 587, pl. 13, fig. 4.
*Globigerina cretacea* EICHENBERG, 1935, (not d'Orbigny), 27er Jahresber. Nieders. Geol. Ver., p. 30, pl. 6, fig. 4.
*Globigerina cretacea* EICHENBERG, 1935, (not d'Orbigny), Oel und Kohle, vol. 11, pt. 23, p. 392, pl. 2B, fig. 15, pl. 5, figs. 53, 54.
*Globigerina infracretacea* GLAESSNER, 1937, Stud. in Micr., vol. 1, pt. 1, p. 28, fig. 1.
*Globigerina cretacea* TAPPAN, (not d'Orbigny), 1940, Jour. Paleontology, vol. 14, pp. 121, 122, pl. 19, fig. 11.
*Globigerina cretacea* TAPPAN, (not d'Orbigny), 1943, vol. 17, p. 512, pl. 82, figs. 16, 17.

Test free, very small, composed of 14–16 chambers, five to six making up last coil. Slightly trochoid. Chambers inflated, distinct, increasing in size as added. Umbilicus small. Aperture not in umbilicus, but at base of last chamber, a curved slit. Sutures distinct, deeply depressed, surface smooth.

*Dimensions.*—Greatest diameter, 0.3 mm., thickness of last chamber, 0.2 mm.

*Discussion.*—This species is characterized by its aperture at the base of the last chamber, by its small size and almost complete lack of sculpture. It is closely related to *G. pseudobulloides* Plummer, but differs in its smaller size and less inflated chambers. Glaessner (1937) reported that this species passes gradually into a *Globigerinella* almost without sculpture. The transition can also be observed in specimens from the Upper Albian of Holland and Germany.

*Occurrence.*—Rare in the Middle Neocomian of Glanerbrug. Recorded from the

Albian of Holland, England, Germany, France, Texas, and Oklahoma, from the Aptian of the Caucasus, England and France, and from the Middle Neocomian of England.

Family ANOMALINIDAE
Subfamily ANOMALININAE
Genus ANOMALINA d'Orbigny 1826
Genotype *Anomalina punctata* d'Orbigny

ANOMALINA SIGMOICOSTA
ten Dam, new species
Plate 32, figures 23, 24

Test free, circular, almost planoconvex. Periphery acute, more or less rounded. Dorsal side more or less flattened, showing only one coil distinctly, preceding coils covered by opaque shell material. Last coil composed of nine, narrow, sigmoidal, depressed chambers. Sutures strongly curved, sigmoidal, thickened, limbate, raised. Ventral side convex with strongly depressed umbilicus. Nine chambers in last coil, very slightly depressed, slightly curved. Sutures thickened, slightly curved, limbate, very slightly raised. Aperture at base of septal face, a narrow slit from the periphery towards umbilicus. Wall calcareous, perforate, surface more or less rough.

*Dimensions.*—Diameter, 0.41 mm.; thickness, 0.21 mm.

*Discussion.*—This species resembles the group *A. complanata* Reuss, *A. intermedia* Berthelin, and *A. berthelini* ten Dam from the Albian, but differs in its sigmoidal sutures on the dorsal side.

*Occurrence.*—Fairly common in Middle Neocomian of Glanerbrug.

*Holotype.*—ten Dam Coll. A679.

## CONCLUSIONS

Seventy-nine species and varieties of Foraminifera are recorded in this fauna; 16 have first been recognized at this locality as follows:

*Anomalina sigmoicosta* n. sp.
*Frondicularia simplicissima* ten Dam
*Lingulina praelonga* ten Dam
*Marginulina hechti* ten Dam
*Nodosaria rugosa* ten Dam
*Planularia guttata* ten Dam
*Pseudopolymorphina eichenbergi* n. sp.
*Quadrainta depressula* ten Dam
*Saracenaria frankei* ten Dam
*Tristix acutangulum lamellosa* ten Dam
*Tristix crassum* ten Dam
*Triplasia grosserugosa* ten Dam
*Vaginulina subrotunda* ten Dam
*Vaginulinopsis pachynota* ten Dam
*Vaginulinopsis reticulosa* ten Dam
*Verneuilina chapmani* ten Dam

Several other species, omitted here, have not been determined because of lack of literature. They will be considered in a later note.

The accompanying table shows the occurrence of the species and varieties present in the Middle Neocomian of Glanerbrug, in contemporaneous formations of other regions, and in the Albian, Upper Cretaceous, Tertiary, and Recent of Europe and America, of 79 species, 47 are known from the Middle Neocomian of Germany, 21 from the Middle Neocomian of England, 32 from the Albian of Europe (four are doubtful), 10 from the Upper Cretaceous, 5 from the Tertiary and Quaternary (these have little stratigraphic significance). No index species are distinguished here, as ranges in other formations of the Lower Cretaceous are incompletely known.

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TABLE 1.—OCCURRENCE OF SPECIES OF FORAMINIFERA OF THE GLANERBRUG MIDDLE NEOCOMIAN FAUNA IN 1, MIDDLE NEOCOMIAN OF GERMANY; 2, MIDDLE NEOCOMIAN OF ENGLAND; 3, ALBIAN; 4, UPPER CRETACEOUS; AND 5, TERTIARY AND RECENT FORMATIONS

| | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|
| *Ammodiscus cretaceous* (Reuss) | | x | x | x | x |
| *Anomalina sigmoicosta* ten Dam, n. sp. | | | | | |
| *Bullopora laevis* (Sollas) | | | x | | x |
| *Citharina acuminata* (Reuss) | | | | | x |
| *Citharina discors* (Koch) | | | | | x |
| *Citharina harpa* (Roemer) | | | | | x |
| *Citharina incrassata* (Reuss) | | | | | x |
| *Citharina intumescens* (Reuss) | | | x | | x |
| *Citharina reticulata* (Cornuel) | | | | | |
| *Dentalina hilseana* Reuss | | | | | x |
| *Dentalina inepta* Reuss | | | | | x |
| *Dentalina serrata* Eichenberg | | | | | x |
| *Eoguttulina anglica* Cushman and Ozawa | | | x | | |
| *Epistomina caracolla* (Roemer) | | | | x | x |
| *Epistomina ornata* (Roemer) | | | | | x |
| *Frondicularia cf. angustissima* Reuss | | | | | |
| *Frondicularia concinna* Koch | | | x | | x |
| *Frondicularia hastata* Roemer | | | | | x |
| *Frondicularia simplicissima* ten Dam | | | | | |
| *Globigerina infracretacea* Glaessner | | | x | x | x |
| *Globulina prisca* Reuss | | x | x | | |
| *Glomospira gordialis* (Jones and Parker) | x | x | x | x | |
| *Haplophragmium aequale* (Roemer) | | | | | x |
| *Haplophragmoides neocomiana* (Chapman) | | | | x | |
| *Lagena acuticosta* Reuss | x | x | x | x | x |
| *Lagena apiculata* (Reuss) | x | x | x | x | x |
| *Lagena cf. hispida* Reuss | | | | | |
| *Lamarckina lamplughi* (Sherlock) | | | x | | |
| *Lamarckina nitens* (Reuss) | | | | | x |
| *Lenticulina münsteri* (Roemer) | | | | x | x |
| *Lenticulina roemeri* (Reuss) | | | | | x |
| *Lenticulina subalata* (Reuss) | | | x | | x |
| *Lingulina nodosaria* Reuss | | | x | | x |
| *Lingulina praelonga* ten Dam | | | | | x |
| *Marginulina acuticosta* Reuss | | | x | | |
| *Marginulina foeda* (Reuss) | | | ? | | x |
| *Marginulina hechti* ten Dam | | | | | x |
| *Marginulina jonesi* Reuss | | | x | x | x |
| *Marginulina robusta* Reuss | | | | | x |

TABLE 1—(*continued*)

| | | | | | |
|---|---|---|---|---|---|
| *Marginulinopsis comma* (Roemer) | | | | | x |
| *Marginulinopsis gracilissima* (Reuss) | | | | x | x |
| *Marssonella oxycona* (Reuss) | | x | x | x | x |
| *Nodosaria obscura* Reuss | | | x | | x |
| *Nodosaria rugosa* ten Dam | | | | | x |
| *Nodosaria sceptrum* Reuss | | | x | | x |
| *Nodosaria tubifera* Reuss | | ? | x | | |
| *Nubecularia antiqua* (Reuss) | | | | | x |
| *Nubecularia triloculina* ten Dam | | | x | | |
| *Nubeculina nodulosa* (Chapman) | | | x | | x |
| *Patellina subcretacea* Cushman and Alexander | | | x | | |
| *Planularia crepidularis* Roemer | | | | x | x |
| *Planularia guttata* ten Dam | | | | | |
| *Pseudoglandulina humilis* (Roemer) | | | ? | | x |
| *Pseudopolymorphina eichenbergi* ten Dam, n. sp. | | | | | x |
| *Quadratina depressula* ten Dam | | | | | |
| *Quadrulina rhabdogonoides* (Chapman) | | | | x | |
| *Ramulina aculeata* Wright | | x | x | x | |
| *Reophax scorpiurus* Montfort | x | x | x | x | |
| *Rhizammina indivisa* Brady | x | x | x | | |
| *Saracenaria bronni* (Roemer) | | | | x | x |
| *Saracenaria frankei* ten Dam | | | | | x |
| *Spirillina minima* Schacko | | x | x | | |
| *Tristix acutangulum* (Reuss) | | | ? | | x |
| *Tristix acutangulum* var. *lamellosa* ten Dam | | | | x | |
| *Tristix crassum* ten Dam | | | | | |
| *Tristix cf. excavatum* (Reuss) | | | | | |
| *Tristix insigne* (Reuss) | | | | x | x |
| *Triplasia grosserugosa* ten Dam | | | | | |
| *Tritaxia pyramidata* Reuss | | | x | | |
| *Trochammina limbata* (Chapman) | | | | x | |
| *Trochammina nonionina* (Reuss) | | | | | x |
| *Vaginulina kochii* var. *striolata* (Reuss) | | | x | | |
| *Vaginulina neocomiana* Chapman | | | | x | x |
| *Vaginulina plana* (Reuss) | | | | | x |
| *Vaginulina protosphaera* Reuss | | | ? | | x |
| *Vaginulina subrotunda* ten Dam | | T | T | | |
| *Vaginulinopsis pachynota* ten Dam | | | T | | |
| *Vaginulopsis reticulosa* ten Dam | | | | | |
| *Verneuilina chapmani* ten Dam | | | | x | |

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# BIBLIOGRAPHY AND INDEX TO NEW GENERA, SPECIES, AND VARIETIES OF FORAMINIFERA FOR THE YEAR 1946

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THE FOLLOWING bibliography lists 356 papers devoted partly or exclusively to Foraminifera. For the year 1946, 243 titles have been compiled. To these are added 113 supplementary titles for the period 1932–1945, as follows: one each for 1932, 1933, and 1936; two for 1935, 1937, and 1938; ten for 1940; eleven each for 1939 and 1941; seventeen each for 1942 and 1943; eighteen for 1944, and twenty for 1945.

Valuable help in compiling the data for this bibliography and index has been received from, and cordial thanks are herewith expressed to Dr. Joseph A. Cushman, Dr. Chalmer L. Cooper, Dr. Walter H. Hegwein, and Dr. Heinrich Hiltermann.

The writer has taken the liberty of assigning a Pleistocene age to the "Foraminifera of Timms Point formation in California," (discussed in numbers 63 and 64 of the following bibliography). He wishes also to point out that publication number 18 is regarded by some workers as dealing with Paleocene rather than the Middle Eocene (see number 77).

The Index to new genera, species, and varieties (subspecies) of Foraminifera for the year 1946 lists as new: 1 family, 14 genera, 1 subgenus, 256 species, 43 varieties, 17 *nomina nova*, 30 *nomina nuda* (regarded as such at the present time) 13 homonyms of which 8 have been changed during 1946, and 103 forms to which the *nomenclatura aperta* was applied. For the period 1939 to 1945 one genus, 15 species, one *nomen novum*, one *nomen nudum*, and four forms with *nomenclatura aperta* are also included.

The five homonyms erected during 1946 and not yet given new names, are as follows:

*Bolivina subangularis* Brady var. *irregularis* Germeraad
*Nodosaria rugosa* ten Dam
*Quinqueloculina transvere-striata* Germeraad
*Robulus alto-costatus* Germeraad
*Sphaerella*, new genus Keller

Information regarding the original species is given in the Index. The writer intends from now on to publish currently detected homonyms among the Foraminifera in "The Micropaleontologist," edited by the Department of Micropaleontology, American Museum of Natural History, New York, and in the "Contributions of the Cushman Laboratory for Foraminiferal Research" in order that authors may propose new names promptly to replace those that are preoccupied.

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## INDEX TO GENERA, SPECIES, AND VARIETIES (SUBSPECIES) OF FORAMINIFERA FOR THE YEAR 1946

*Acruliammina* gen. nov. Loeblich and Tappan, Jour. Paleontology, vol. 20, p. 252. Family: Placopsilinidae; subfamily: Placopsilininae. Genotype: *Placopsilina longa* Tappan, 1940, Jour. Paleontology, vol. 14, p. 100, pl. 15, figs. 9, 10. Lower Cretaceous.

*Afghanella* gen. nov., Thompson, Jour. Paleontology, vol. 20, p. 152. Family: Fusulinidae. Genotype: *Afghanella schencki* Thompson, 1946, *ut infra*. Permian.

——— *schencki* Thompson, *ibid.*, vol. 20, p. 153, pl. 25, figs. 1–12. Permian, Northern Afghanistan. For: *Neoschwagerina annae* Hayden, 1909, Rec. Geol. Surv. India, vol. 38, p. 250, pl. 22, figs. 8–14; for: *Neoschwagerina (Sumatrina) annae* in: Furon, 1927, L'Hindou-Kouch et le Kaboulistan, p. 64, pl. 3; and for: *Neoschwagerina sumatrinaeformis* Gubler, 1935, pro parte, Mem. Soc. géol. France, new series, vol. 11, Mem. No. 26, p. 153.

*Alveolina lacunata* de Cizancourt, (nom. nov.), Soc. géol. France, Comptes-rendus, fasc. 16, p. 335. New name for: *Assilina umbilicata* de Cizancourt, 1938, (non Rutten, 1915), Mém. Soc. Géol. France, new series, vol. 17, fasc. 1, Mém. No. 39, p. 23, pl. 3, figs. 19, 20, 27; text fig. 2-c. Ypresian, Afghanistan.

*Ammobaculites bergquisti* Cushman and Applin, Contr. Cushman Lab. Foram. Res., vol. 22, p. 73, pl. 13, figs. 4, 5. Basal Upper Cretaceous, Texas.

——— *braunsteini* Cushman and Applin, *ibid.*, vol. 22, p. 74, pl. 13, fig. 7. Basal Upper Cretaceous, Mississippi.

——— *comprimatus* Cushman and Applin, *ibid.*, vol. 22, p. 73, pl. 13, fig. 3. Basal Upper Cretaceous, Texas.

——— *jarvisi* Cushman and H. H. Renz, Cushman Lab. Foram. Res., Spec. Publ. 18, p. 19, pl. 2, figs. 8, 9. Uppermost Cretaceous, Trinidad, British West Indies.

——— *junceus* Cushman and Applin, Contr. Cushman Lab. Foram. Res., vol. 22, p. 72, pl. 13, fig. 2. Basal Upper Cretaceous, Texas,

——— *obscurus* Loeblich, Jour. Paleontology. vol. 20, p. 135, pl. 22, fig. 6. Upper Cretaceous, Texas.

——— *polythalamus* Loeblich, *ibid.*, vol. 20, p. 135, pl. 22, fig. 7. Upper Cretaceous, Texas.

*Ammobaculoides gainesvillensis* Loeblich and Tappan, *ibid.*, vol. 20, p. 244, pl. 35, figs. 5, 6. Lower Cretaceous, Texas.

——— *plummerae* Loeblich, *ibid.*, vol. 20, p. 137, pl. 22, figs. 10–12; test fig. 3. Upper Cretaceous, Texas.

*Ammodiscus cretacens* (Reuss, 1845) var. *rugosa* Schijfsma, Mededeel. Geol. Sticht. Haarlem, series C, vol. V, No. 7, p. 28, pl. 6, fig. 2. Hervian (Campanian) Southern Limburg, Holland. (Note: The varietal name is preoccupied by: *Ammodiscus rugosa* Terquem, 1886, Mém. Soc. géol. France, series 3, vol. 4, p. 9, pl. 1, fig. 15).

——— *planus* Loeblich, Jour. Paleontology, vol. 20, p. 133, pl. 22, fig. 2. Upper Cretaceous, Texas.

*Ammomarginulina bellensis* Loeblich, *ibid.*, vol. 20, p. 135, pl. 22, fig. 8. Upper Cretaceous, Texas.

*Amphistegina elliotti* Cushman and Stainforth, Contr. Cushman Lab. Foram. Res., vol. 22, p. 118, pl. 20, figs. 1–6. Middle Eocene, northwestern Ecuador.

*Anomalina bundensis* van Bellen, Proefschrift (Thesis) Univ. Utrecht, p. 73. pl. 11, figs. 1–3. Middle Eocene. Holland.

——— *daini* Schijfsma, Mededeel. Geol. Sticht. Haarlem, series C, vol. V, No. 7, p. 98, pl. 6, fig. 3. Upper Cretaceous, South Limburg, Holland. For: *Anomalina ammonoides* Dain, 1934, (*non Rosalina ammonoides* Reuss, 1844), Trans. Geol. Oil Inst. Leningrad-Moscow, series A, No. 43, p. 43, pl. 5, fig. 50.

——— ——— Schijfsma, 1946, var. *arenacea* Schijfsma, *ibid.*, series 3, vol. V, No. 7, p. 99, pl. 6, fig. 4. Upper Cretaceous, South Limburg, Holland.

——— *menneri* Keller, Bull. Soc. Natural. Moscou, vol. 51, new series, Sect. géol. vol. 21, p. 103, pl. 1, figs. 14–16; pl. 3, figs. 16, 17. Upper Cretaceous, Caucasus.

*Assilina sublacunata* de Cizancourt (nom. nov.), Soc. géol. France, Comptes-rendus, fasc. 16, p. 335. New name for: *Assilina subumbilicata* de Cizancourt, 1938, Mém. Soc. géol. France, new ser. vol. 17, fasc. 1, Mem. No. 39, p. 24, pl. 3, figs. 21–23. Ypresian, Afghanistan. [Note: This change of name is not justified according to the Int. Rules of Zool. Nomencl. Madame de Cizancourt rightly changed her homonym, *Assilina umbilicata*, 1938, on account of the existence of *Nummulites* (*Assilina*) *umbilicata* Rutten, 1915. There is, however, no need for a change of *subumbilicata* into *sublacunata* as long as the former specific name is not preoccupied.]

*Asterigerina byramensis* Cushman and Todd, Contr. Cushman Lab. Foram. Res., vol. 22, p. 101, pl. 16, figs. 28, 29. Oligocene, Byram Marl, Mississippi.

*Ataxogyroidina dufouri* Schijfsma, Mededeel. Geol. Sticht. Haarlem, series C, Vol. V, No. 7, p. 37, pl. 1, fig. 9. Upper Cretaceous, South Limburg, Holland.

——— *pseudoglobosa* Schijfsma, *ibid.*, series C, vol. V, No. 7, p. 37, pl. 1, fig. 11. Upper Cretaceous, South Limburg, Holland. For: *Ataxogyroidina globosa* Marie, 1941, (*non Nonionina globosa* von Hagenow, 1842) Mém. Mus. Nation. Hist. Nat. Paris, vol. 12, pt. 1, p. 59, pl. 5, figs. 50–57.

*Bigenerina clavellata* Loeblich and Tappan, Jour. Paleontology. vol. 20, p. 245, pl. 35, figs. 7, 8. Lower Cretaceous, Texas.

*Boldia* nom. nov. van Bellen. Contr. Cushman Lab. Foram. Res., vol. 22, p. 122. New genus name for *Terquemia* van Bellen, 1946 (*non Terquemia* Tate, 1868, *nec* van Veen, 1932). Family: Rotaliidae. Genotype: *Rotalina lobata* Terquem, 1882, Mém. Soc. géol. France, (3), vol. 2, p. 63, pl. 4, fig. 10. Eocene. (Note: On July 8, 1946, van Bellen, in his thesis, published the homonym *Terquemia;* a few days later, on July 11, 1946. van den Bold introduced "*Boldia* van Bellen *in litt.*," in his thesis; van Bellen, the original author of the homonym officially legalized the name *Boldia* in the above cited reference on December 7, 1946.)

——— *vandersluisi* van den Bold, Proefschrift (Thesis), Univ. Utrecht, p. 124, pl. 18, fig. 6. Lower Eocene (or Paleocene), Guatemala.

*Bolivina alazanensis* Cushman, 1927, var. *primaeva* Cushman, Cushman Lab. Foram. Res., Spec. Publ. No. 16, p. 27, pl. 5, fig. 12. Upper Eocene, Alabama. For: *Bolivina alazanensis* in Cushman, 1926, pro parte, *ibid.*, Spec. Publ. No. 9, pl. 8, fig. 7 (*non* fig. 6).; and for: *Bolivina alazanensis* in Cushman and Todd, *ibid.*, Contr., vol. 21, 1945, p. 97, pl. 15, fig. 22.

——— *dissentiata* Cushman and Todd. nom. nov., *ibid.*, Contr., vol. 22, p. 120. New name for: *Bolivina imporcata* Cushman and Todd, 1945, (*non* Cushman and H. H. Renz, 1944), *ibid.*, Spec. Publ. No. 15, p. 47, pl. 7, fig. 14. Miocene, Jamaica.

——— *gracilis* Cushman and Applin, 1926, var. *incisurata* Cushman, *ibid.*, Spec. Publ. No. 16, p. 26, pl. 5, fig. 9. Upper Eocene, Alabama. For: *Bolivina gracilis* Cushman and Applin, 1926, var. *danvillensis* Howe and Wallace, 1932 (*non Bolivina danvillensis* Howe and Wallace, 1932), Louisiana Geol. Surv. Bull. No. 2, p. 57, pl. 11, fig. 7; for same reference in: Cushman Lab. Foram. Res., Spec. Publ. No. 9, 1937, p. 59, pl. 7, fig. 24; and for same reference in: Cushman and Todd, 1945, Cushman Lab. Foram. Res., Contr., vol. 21, p. 96, pl. 15, fig. 18.

——— *indopacifica* Germeraad, in Rutten and Hotz, Geol. Petrogr. and Palaeont. Results, Ceram, (3), Geol. No. 2, p. 68, pl. 2, figs. 13, 14. Pliocene, Central Ceram.

——— *rugosa* Parr, Nation. Mus. Victoria, Mem., No. 14, pt. 2, p. 126, text figs. a, b. Post-Tertiary, boring near Rosebud, Victoria, Australia, 177–178 feet.

——— *seranensis* Germeraad, in Rutten and Hotz, Geol., Petrogr. and Geol. Results, Ceram (3), Geol. No. 2, p. 68, pl. 3, figs. 20, 21, Pliocene. Central Ceram.

——— *subadvena* Cushman, 1926, var. *acuminata* Natland, MS., in Cushman and Gray, Cushman Lab. Foram. Res., Spec. Publ. No. 19, p. 34, pl. 5, fig. 46. Pliocene (*recte* Pleistocene), California. For: *Bolivina subadvena* Cushman, 1926, var. *serrata* Natland, 1938, (*non* Chapman, 1892, *nec* Wright, 1900). Bull. Scripps Inst. Oceanogr., Techn. Series, vol. 4, No. 5, p. 145, pl. 5, figs. 8, 9; and for same variety in:

Cushman and McCulloch, 1942, Allan Hancock Pacific Exped., vol. 6, No. 4, p. 213, pl. 24, fig. 14; pl. 27, figs. 1, 2.

——— *subangularis* Brady, 1881, var. *irregularis* Germeraad, in Rutten and Hotz, Geol., Petrogr., and Palaeont. Results. Ceram, (3), Geol. No. 2, p. 68, pl. 3, figs. 15, 16. Pliocene, Central Ceram. (Note: The varietal name is preoccupied by *Bolivina irregularis* Terquem, 1882, Mém. Géol. Soc. France, (3), vol. 2, No. 3, p. 149, pl. 15, fig. 21).

*Bolivinoides sotchicus* Keller, Bull. Soc. Natural. Moscou, new series, vol. 51, sect. geol. vol. 21, p. 92, pl. 2, fig. 10. Upper Cretaceous, Caucasus.

*Bulimina byramensis* Cushman and Todd, Contr. Cushman Lab. Foram. Res., vol. 22, p. 91, pl. 15, figs. 25, 26. Oligocene, Byram Marl, Mississippi.

——— *petroleana* Cushman and Heelberg, 1941, var. *spinea* Cushman and H. H. Renz, Cushman Lab. Foram. Res., Spec. Publ. No. 18, p. 37, pl. 6, fig. 13. Uppermost Cretaceous, Trinidad, British West Indies.

——— *stokesi* Cushman and H. H. Renz, *ibid.*, Spec. Publ. No. 18, p. 37, pl. 6, fig. 14. Uppermost Cretaceous, Trinidad, British West Indies.

——— *subornata* Brady, 1884, var. *moluccensis* Germeraad, in Rutten and Hotz, Geol., Petrogr. and Palaeont. Results, Ceram, (3), Geol. No. 2, p. 68, pl. 3, fig. 13. Pliocene, Central Ceram.

——— (*Desinobulimina*) *suteri* Cushman and H. H. Renz, Cushman Lab. Foram. Res., Spec. Publ. No. 18, p. 38, pl. 6, fig. 15. Uppermost Cretaceous Trinidad, British West Indies.

*Buliminella beaumonti* Cushman and H. H. Renz, *ibid.*, Spec. Publ. No. 18, p. 36, pl. 6, fig. 7. Uppermost Cretaceous, Trinidad, British West Indies.

*Calcarina umbilicata* Germeraad, in Rutten and Hotz, Geol., Petrogr. and Paleaont. Results, Ceram, (3), Geol. No. 2, p. 71, pl. 4. figs. 2–5. Pliocene, Central Ceram.

*Cancris cocoaensis* Cushman, Cushman Lab. Foram. Res., Spec. Publ. No. 16, p. 35, p. 7, fig. 5. Upper Eocene, Alabama. For: *Cancris brongniartii* Cushman, 1935, (*non* d'Orbigny, 1826), U. S. Geol. Surv., Prof. Pap. 181, p. 48, pl. 20, fig. 1; and for: *Cancris sp.* Cushman and Todd, 1942, Cushman Lab. Foram. Res., Contr., vol. 18, p. 90, pl. 23, figs. 3, 4.

——— *lobatula* Germeraad, in Rutten and Hotz, Geol., Petrogr., and Palaeont. Results, Ceram, (3), Geol. No. 2, p. 70, pl. 3, fig. 28; pl. 4, figs. 9, 10. Pliocene, Central Ceram.

——— *moluccensis* Germeraad, *ibid.*, (3), Geol. No. 2, p. 72, pl. 2, figs. 29–32. Pliocene, Central Ceram.

———*pacifica* Cushman, 1925, var. *rotunda* Germeraad, *ibid.*, (3), Geol. No. 2, p. 72, pl. 2, fig. 28. Pliocene, Central Ceram.

*Cassidulinoides howei* Cushman, Cushman Lab. Foram. Res., Spec. Publ. No. 16, p. 36, pl. 7, fig. 10. Upper Eocene, Alabama. For: *Cassidulinoides braziliensis* Howe and Wallace, 1932, (*non* Cushman, 1922), Louisiana Geol. Bull. vol. 2. p. 72, pl. 10. fig. 6.

——— *seranensis* Germeraad, in Rutten and Hotz, Geol. Petrogr. and Palaeont. Results, Ceram, (3), Geol. No. 2, p. 72, pl. 5, figs. 5, 6. Pliocene, Central Ceram.

*Ceratobulimina bundensis* van Bellen, Proefschrift (Thesis) Univ. Utrecht, p. 68, pl. 9, figs. 13–18. Middle Eocene, Holland.

——— *gaultina* Ten Dam, nom. nov., Bull. Soc. geol. France, (5), vol. 16, p. 11, text fig. 1. Albian, Holland. (Published February 1947). For: *Pulvinulina hauerii* Chapman, 1898, (*non* d'Orbigny, 1846), Jour. R. Micr. Soc. London, (2), vol. 18, p. 5, pl. 1, fig. 7.

*Chrysalogonium arkansanum* Cushman and Todd, Cushman Lab. Foram. Res., Contr., vol. 22, p. 52, pl. 9, figs. 1, 2. Paleocene, Arkansas. For: *Chrysalogonium* cf. *texanum* Cushman, 1940, *ibid.*, Contr., vol. 16, p. 60, pl. 10, fig. 14.

———*eocenicum* Cushman and Todd, *ibid.*, Contr., vol. 22, p. 53, pl. 9, figs. 3–5. Paleocene, Arkansas.

*Cibicides americanus* (Cushman, 1918), var. *bundensis* van Bellen, Proefschrift (Thesis), Univ. Utrecht, p. 77, pl. 11, figs. 19–21. Middle Eocene, Holland.

——— *choctawensis* Cushman and McGlamery, 1938, var. *dorso-involuta* van Bellen, nom. nov., Cushman Lab. Foram. Res., Contr., vol. 22, p. 122. Middle Eocene, Holland. New name for: *Cibicides choctawensis* Cushman and McGlamery, 1938, var. *ornata* van Bellen, 1946, *non* Cushman, 1918), Proefschrift (Thesis) Univ. Utrecht, p. 79, pl. 12, figs. 7–9.

——— ——— ——— ——— var. *ornata* van Bellen, Proefschrift (Thesis), Univ. Utrecht, p. 79, pl. 12, figs. 7–9. [Note: On account of homonymy with *Truncatulina* (*Cibicides*) *lobatula* (Walker and Jacob) var. *ornata* Cushman, 1918, Bull. 676, U. S. Geol. Surv., p. 61, pl. 18, figs. 1, 2, van Bellen changed his name to *D. choctawensis* Cushman and McGlamery, var. *dorso-involuta*, *ut supra*.]

——— *elongatus* (d'Orbigny, 1850) var. *limburgensis* van Bellen, *ibid.*, p. 80, pl. 12, figs. 10–12, Middle Eocene, Holland.

——— *fenestratus* Detling, Jour. Paleontology, vol. 20, p. 359, pl. 51, figs. 4, 5. Eocene, Oregon, U. S. A.

——— *geleensis* van Bellen, Proefschrift (Thesis) Univ. Utrecht, p. 80, pl. 12 figs. 13–15. Middle Eocene, Holland.

——— *haastersi* van den Bold, Proefschrift (Thesis) Univ. Utrecht, p. 125, pl. 18, fig. 9. Lower Eocene Guatemala and Honduras.

——— *irenae* van Bellen, Proefschrift (Thesis) Univ. Utrecht. p. 82, pl. 12, figs. 19–21. Middle Eocene, Holland. For: *Cibicides praecursorius* Cushman and Ponton, 1932, (*non* Schwager, 1883), Cushman Lab. Foram. Res., Contr., vol. 8, p. 72, pl. 9, fig. 14.

——— *minimalis* Schijfsma, Mededeel. Geol. Stichting Haarlem, series C, vol. V, No. 7, p. 104, pl. 7, fig. 11. Upper Cretaceous, Limburg, Holland.

——— *pseudopraecursorius* van Bellen, Proef-

schrift, (Thesis), Univ. Utrecht, p. 83, pl. 13, figs. 1–3. Middle Eocene, Holland. For: *Cibicides praecursorius* ten Dam, 1944, (*non.* Schwager, 1883), Mededeel. Geol. Stichting Haarlem, series, C, vol. V, No. 3, p. 134, pl. 5, fig. 11.

?——— *vanbelleni* van den Bold, Proefschrift, (Thesis), Univ. Utrecht, p. 125, pl. 18, fig. 8. Lower Eocene, Guatemala and British Honduras.

——— *vanrijsingei* van Bellen, Proefschrift, (Thesis), Univ. Utrecht, p. 85, pl. 13, figs. 10–12. Middle Eocene, Holland.

——— *voltziana* (d'Orbigny, 1840), var. *plana* Schijfsma, Mededeel. Geol. Stichting Haarlem, ser. C., vol. V, No. 7, p. 104, pl. 5, fig. 7. Upper Cretaceous, Limburg, Holland.

*Cribrononion* subgen. nov. Thalmann, Eclog. geol. Helv., vol. 39, No. 2, (published July 31, 1947), p. 312. New subgenus of *Nonion* Montfort 1808. Subgenotype: *Nonionina heteropora* Egger, 1857, N. Jarhb. f. Min. etc., p. 300, pl. 14, figs. 19–21. Miocene, Bavaria, Germany.

*Cribropyrgo* gen. nov. Cushman and Bermudez, Cushman Lab. Foram. Res., Contr., vol. 22, p. 119. Family (not stated): Miliolidae, Genotype: *Cribropyrgo robusta* Cushman and Bermudez, 1946, *ut infra.* Recent.

——— *robusta* Cushman and Bermudez, *ibid.*, vol. 22, p. 119, pl. 20, figs. 7–9, Recent, off Cienfugos, Cuba, 1075 fathoms.

*Dentalina californica* Cushman and Gray, Cushman Lab. Foram. Res., Contr., vol. 22, p. 66, pl. 12, figs. 3–5. Pliocene (*recte* Pleistocene) California.

——— *cooperensis* Cushman, 1933, var. *gracilescata* Cushman, *ibid.*, Spec. Publ. No. 16, p. 13, pl. 3, fig. 15. Upper Eocene, Alabama.

——— *jamaicensis* Cushman and Todd, nom. nov., *ibid.*, Contr., vol. 22, p. 120. New name for: *Dentalina jarvisi* Cushman and Todd. 1945, (*non* Montagne, 1941), *ibid.*, Spec. Publ. No. 15, p. 22, pl. 3, fig. 22. Miocene, Jamaica.

——— *pseudo-nasuta* Cushman and Todd, *ibid.*, Contr., vol. 22, p. 51, pl. 8, figs. 13, 14. Paleocene, Arkansas. For: *Dentalina* cf. *pungens* Cushman, 1939 (*non* Reuss, 1951), *ibid.*, Contr., vol. 15, p. 57, pl. 10, fig. 9.

*Desinobulimina* see *Bulimina*

*Dictyoconus valentinus* Almela. Inst. Geol. Min. Espana, Notas y Comm., No. 16, p. 5, pl. 1, figs. 1–15. Cenomanian, Valencia, Spain.

*Discorbis bundensis* van Bellen, Proefschrift, (Thesis), Univ. Utrecht, p. 47, pl. 4, figs. 19–24. Middle Eocene, Holland.

——— *confusa* van Bellen, nom. nov., Cushman Lab. Foram. Res., Contr., vol. 22, p. 123. Middle Eocene Holland, New name for: *Discorbis patellinaformis* van Bellen, 1946, *ut infra.*

——— *conica* van Bellen, Proefschrift, (Thesis), Univ. Utrecht, p. 48, pl. 5. figs. 4–6. Middle Eocene, Holland.

——— *limburgensis* van Bellen, *ibid.*, p. 52, pl. 5, figs. 23–28. Middle Eocene, Holland.

——— *oligocenica* Cushman and Todd, nom. nov., Cushman Lab. Foram. Res., Contr., vol. 22, p. 97, pl. 16, figs. 9, 14. Oligocene, Byram Marl, Mississippi. New name for: *Truncatulina byramensis* Cushman, 1922, U. S. geol. Surv. Prof. Pap. 129–E, p. 96, pl. 20, figs. 4–6.

——— *patellinaformis* van Bellen, Proefschrift, (Thesis), Univ. Utrecht, p. 52, pl. 6, figs. 1–3. Middle Eocene, Holland. For: *Patellina nitida* Terquem, 1882, Mem. Soc. geol. France, (3), vol. 2, p. 123, pl. 20, fig. 38. (Note: Since this new form is a near-homonym of *Discorbis patelliformis* Brady, 1884, Rept. Challenger, Zool., vol. 9, p. 647, pl. 88, fig. 3; pl. 89, fig. 1, van Bellen changed the name to *Discorbis confusa* nom. nov., *ut supra.*)

——— *plana* van Bellen, *ibid.*, p. 53, pl. 6, figs. 4–9, Middle Eocene, Holland. (Note: On account of homonymy with *Discorbis plana* Heron-Allen and Earland, 1932, and with *Discorbis plana* Brotzen, 1936, the author has changed his name to *Discorbis rutteni* nom. nov., *ut infra.*)

——— *rutteni* van Bellen, nom. nov., Cushman Lab. Foram. Res., Contr., vol. 22, p. 121. New name for: *Discorbis plana* van Bellen, 1946, *ut supra.* (*nec* Heron-Allen and Earland, 1932, *nec* Brotzen, 1936).

——— *sigmoidalis* Schijfsma, Mededeel. Geol. Stichting Haarlem, ser. C, vol. V, No. 7, p. 83, pl. 4, fig. 12. Upper Cretaceous, Holland.

——— *supracretacea* Schijfsma, *ibid.*, ser. C., vol. V, No. 7, p. 83, pl. 4, fig. 10. Upper Cretaceous, Holland.

——— *terquemi* van Bellen, Proefschrift, (Thesis) Univ. Utrecht, p. 85. For: *Rotalina involuta* Terquem, 1882, (*non* Reuss, 1862), Mem. Soc. geol. France, (3), vol. 2, p. 76, pl. 15, fig. 10. Eocene, France.

*Dunbarinella concisa* Thompson and Hazzard, Geol. Soc. America, Mem. No. 17, p. 42, pl. 11, figs. 8–12. Permian, Southern California.

*Ellipsonodosaria midwayensis* Cushman and Todd, Cushman Lab. Foram. Res., Contr., vol. 22, p. 61, pl. 10, fig. 25. Paleocene, Arkansas. For: *Nodosaria spinulosa* Plummer, (1926), 1927, (*non Nautilus spinulosus* Montagu, 1808), Univ. Texas Bull. 2644, p. 84, pl. 4, fig. 19.

——— *paleocenica* Cushman and Todd, *ibid.*, vol. 22, p. 61, pl. 10, fig. 26. Paleocene, Arkansas. For: *Ellipsonodosaria* sp. Cushman, 1940, *ibid.*, vol. 16. p. 70, pl. 12, figs. 1, 2.

*Elphidiella indopacifica* Germeraad, in Rutten and Hotz, Geol., Petrogr. and Palaeont. Results, Ceram, (3), Geol. No. 2, p. 67, pl. 3, figs. 3, 4. Recent, Ceram.

*Entosolenia orbignyana* (Seguenza, 1862) var. *praeclara* Cushman and H. H. Renz, Cushman Lab. Fora. Res., Spec. Publ. No. 18, p. 38 pl. 6, fig. 18. Uppermost Cretaceous, Trinidad, British West Indies. For: *Lagena orbignyana* Cushman and Jarvis, 1932, (*non* Seguenza, 1862), Proc. U. S. Nat. Mus., vol. 80, Art. 14, p. 40, pl. 12, fig. 7.

*Eouvigerina laxistoma* Loeblich and Tappan, Jour. Paleontology, vol. 20, p. 254, pl. 37, figs. 10–12. Lower Cretaceous, Texas.

*Epistomina lacunosa* Loeblich and Tappan, *ibid.*, vol. 20, p. 256, pl. 37, figs. 16, 17. Lower Cretaceous, Texas.

——— *scaphiolocula* Loeblich and Tappan, *ibid.*, vol. 20, p. 256, pl. 37, fig. 18. Lower Cretaceous, Texas.

——— *suturo-limbaya* Germeraad, in Rutten and Hotz, Geol. Petrogr. and Palaeont. Results, Ceram, (3), Geol. 2, p. 70, pl. 2, figs. 23–25. Pliocene, Ceram.

*Eponides acria* Loeblich and Tappan, Jour. Paleontology, vol. 20, p. 255, pl. 37, fig. 13. Lower Cretaceous, Texas.

——— *beisseli* Schijfsma, Mededeel. Geol. Stichting Haarlem, ser. C. vol. V, No. 7, p. 84, pl. 4, fig. 13. Upper Cretaceous, Holland. For: *Rotalia species* Beissel, 1891, Abhandl. k. Preuss. geol. Landes-Anst., n.s., vol. 3, p. 73, pl. 14, figs. 20–24.

——— *bollii* Cushman and H. H. Renz, Cushman Lab. Foram. Res., Spec. Publ. No. 18, p. 44, pl. 7, fig. 23. Uppermost Cretaceous, Trinidad, British West Indies.

——— *brönnimanni* Cushman and H. H. Renz, *ibid.*, Spec. Publ. No. 18, p. 45, pl. 7, fig. 24. Uppermost Cretaceous, Trinidad, British West Indies.

——— ——— ——— ——— var. *mera* Cushman and H. H. Renz, *ibid.*, Spec. Publ. No. 18, p. 45, pl. 7, fig. 25. Uppermost Cretaceous, Trinidad, British West Indies.

——— *gratus* van Bellen, Proefschrift, (Thesis), Univ. Utrecht, p. 58. For: *Pulvinulina byramensis* Cushman, 1922, U. S. Geol. Surv. Prof. Pap. 129–E, p. 99, pl. 22, figs. 4, 5.; for: *Eponides jacksonensis* (Cushman and Applin, 1926) in Cushman, 1935, *ibid.*, Prof.-Pap. 181, p. 46, pl. 19, figs. 4–8; and for: *Pulvinulina jacksonensis* Cushman and Applin, 1926, Bull. Amer. Assoc. Petrol. Geologists, vol. 10, p. 181, pl. 9, figs. 24, 25.

——— *stilbius* Loeblich and Tappan, Jour. Paleontology, vol. 20, p. 225, pl. 37, figs. 14, 15. Lower Cretaceous, Texas.

——— *zinkstoki* van Bellen, nom. nov., Cushman Lab. Foram. Res., Contr., vol. 22, p. 121. Middle Eocene, Holland. New name for: *Eponides budensis* (Hantken) in van Bellen, 1946, (*non Truncatulina budensis* Hantken, 1875), Proefschrift (Thesis), Univ. Utrecht, p. 56, pl. 7, figs. 1–3.

*Frondicularia simplicissima* ten Dam, Jour. Paleontology, vol. 20, p. 576, pl. 88, fig. 11. Neocomian, Holland.

*Gaudryina bosquensis* Loeblich and Tappan, *ibid.*, vol. 20, p. 245, pl. 35, figs. 12, 13; text fig. 3. Lower Cretaceous, Texas. For: *Gaudryina gradata* Plummer, 1931, (*non* Berthelin, 1880), Texas Univ. Publ., 3101, p. 136, pl. 8, fig. 12.

——— *bundensis* van Bellen, Proefschrift (Thesis), Univ. Utrecht, p. 27, pl. 1, figs. 14–17. Middle Eocene, Holland.

——— (*Siphogaudryina*) *seranensis* Germeraad, in Rutten and Hotz, Geol., Petrogr. and Palaeont. Results, Ceram, (3), Geol. No. 2, p. 62, pl. 1, figs. 8, 9. Pliocene, Ceram.

*Globigerinoides korotkovi* Keller, Bull. Soc. Natural. Moscou, n. s., vol. 51, sect. géol. vol. 21, p. 98, pl. 2, figs. 14–16. Upper Cretaceous, Caucasus.

*Globorotalia globigeriniformis* van Bellen, Proefschrift (Thesis), Univ. Utrecht, p. 71, pl. 10, figs. 10–12. Middle Eocene, Holland.

——— *lacerti* Cushman and H. H. Renz, Cushman Lab. Foram. Res., Spec. Publ. No. 18, p. 47, pl. 8, figs. 13, 14, Uppermost Cretaceous, Trinidad, British West Indies.

——— *marginaculeata* Loeblich and Tappan, Jour. Paleontology, vol. 20, p. 257, pl. 37, figs. 19–21; text fig. 4–A. Lower Cretaceous, Texas.

——— *pshadae* Keller, Bull. Soc. Natural. Moscou, n. s., vol. 51. sect. géol. vol. 21, p. 99, pl. 2, figs. 4–6. Upper Cretaceous, Caucasus.

——— *subbotinae* Morozova, nom. nov., Acad. Sci. URSS., Comptes-rendus (Doklady), vol. 54, p. 53, footnote. Lower Eocene, Ypresian, Crimea and Caucasus. New name for: *Globorotalia* ex gr. *canariensis* of Russian authors.

*Glomospira gordialis* (Jones and Parker, 1860), var. *diffundens* Cushman and H. H. Renz, Cushman Lab. Foram. Res., Spec. Publ. No. 18, p. 15, pl. 1, fig. 30. Uppermost Cretaceous, Trinidad, British West Indies.

——— *watersi* Loeblich, Jour. Paleontology, vol. 20, p. 134, pl. 22, figs. 3, 4; text fig. 1. Upper Cretaceous, Texas.

*Gyroidina byramensis* Cushman and Todd, Cushman Lab. Foram. Res., Contr., vol. 22, p. 98, pl. 16, figs. 19–21. Oligocene, Byram Marl, Mississippi.

——— *moskvini* Keller, Bull. Soc. Natural. Moscou, n. s., vol. 51, sect. géol. vol. 21, p. 93, pl. 1, figs. 1–3. Upper Cretaceous, Caucasus.

——— *tendami* Schijfsma, Mededeel. Geol. Stichting Haarlem, ser. C, vol. V, No. 7, p. 86, pl. 5, fig. 3. Upper Cretaceous, Holland.

*Haplophragmium abkhasicum* Keller, Soc. Natural, Moscou, Bull., n. s., vol. 51, sect. géol. vol. 21, p. 89, pl. 1, fig. 17; pl. 3, fig. 19. Upper Cretaceous, Caucasus.

——— *fallax* Keller, *ibid.*, vol. 51, sect. géol. vol. 21, p. 89, pl. 3, fig. 15. Upper Cretaceous, Caucasus.

*Haplophragmoides cushmani* Loeblich and Tappan, Jour. Paleontology, vol. 20, p. 244, pl. 35, fig. 4. Lower Cretaceous, Texas.

——— *flagleri* Cushman and Hedberg, 1941, var. *trinitatensis* Cushman and H. H. Renz, Cushman Lab. Foram. Res., Spec. Publ. No. 18, p. 18, pl. 2, figs. 2, 3. Uppermost Cretaceous, Trinidad, British West Indies.

——— *platus* Loeblich, Jour. Paleontology, vol. 20, p. 134, pl. 22, fig. 5. Upper Cretaceous, Texas.

*Hauerina atlantica* Cushman, Cushman Lab. Foram. Res., Contr. vol. 22, p. 8, pl. 1, figs. 25, 26. Recent, San Juan Harbor, Porto Rico. For: *Hauerina bradyi* Cushman 1921 (*non* Cushman, 1917), Proc. U. S. Nat. Mus., vol. 59, p. 72; for: same reference in: Cushman, 1922, Publ. 311, Carnegie Inst. Washington, p. 71; for same reference in: Cushman, 1929, Bull. 104, U. S. Nat. Mus., p. 47, pl. 10, figs.

4–9, part 6; and for same reference in: Cushman, 1941, Smithson. Miscellan. Coll., vol. 99, No. 9, p. 5, pl. i, figs. 25–27.

——— *diversa* Cushman, *ibid.*, vol. 22, p. 11, pl. 2, figs. 16–19. Recent, Indo-Pacific, shallow waters off Paumotu Island. For: *Hauerina bradyi* Cushman, 1932 (*non* Cushman, 1917), Bull. 161. pt. 1, U. S. Nat. Mus., p. 44, pl. 10, figs. 12–15.

——— *involuta* Cushman, *ibid.*, vol. 22, p. 13, pl. 2, figs. 25–28. Recent, Indo-Pacific, Rongelab Atoll, Marshall Islands. For: *Hauerina ornatissima* Brady, 1884, (*non* Karrer, 1868), Rept. Voyage Challenger, Zool., pt. 9, p. 192, pl. 7, figs. 15–17 (*non* figs. 18–22) and for same reference in: Cushman, 1932, Bull. 161, pt. 1, U. S. Nat. Mus., p. 43 (not pl. 10, figs. 16, 17).

——— *miocenica* Cushman, *ibid.*, vol. 22, p. 6, pl. 1, fig. 17; pl. 2, fig. 11. Miocene, Florida. For: *Hauerina bradyi* Cushman and Ponton, 1932, (*non* Cushman, 1917), Florida Geol. Surv., Bull. 9, p. 50, pl. 6, fig. 1.

——— *occidentalis* Cushman, *ibid.*, vol. 22, p. 9, pl. 1, figs. 22–24. Recent, Dry Tortugas, Florida, 7 fathoms. For: *Hauerina ornatissima* Cushman, 1929 (*non* Karrer, 1868, *Quinqueloculina*), U. S. Nat. Mus., Bull. 104, pt. 6, p. 47, pl. 10, figs. 10–12.

——— *orientalis* Cushman, *ibid.*, vol. 22, p. 12, pl. 2, figs. 22–24. Recent, Indo-Pacific, off Samoa, 17 fathoms. For: *Hauerina ornatissima* Brady, 1884 (*non* Karrer, 1868), Rept. Voyage Challenger, Zool., vol. 9, p. 192, pl. 7, figs. 18–20 (*nec* figs. 15–17, 21, 22); for same reference in: Cushman, 1917, U. S. Nat. Mus., Bull. 71, pt. 6, p. 63, pl. 23, figs. 1, 5; for same reference in: Cushman, 1924, Carnegie Inst. Washington, Publ. 342, p. 67, pl. 24, figs. 7–9; and for same reference in: Cushman, 1932, U. S. Nat. Mus., Bull. 161, pt. 1, p. 43, pl. 10, figs. 16, 17.

——— *parri* Cushman, *ibid.*, vol. 22, p. 6, pl. 1, fig. 18. Oligocene, Victoria, Australia.

*Hormosina globulifera* Brady, 1879, var. *trinitatensis* Cushman and H. H. Renz, Cushman Lab. Foram. Res., Spec. Publ. No. 18, p. 14, pl. 1, figs. 15–19. Uppermost Cretaceous, Trinidad, British West Indies. For: *Hormosina globulifera* Cushman and Jarvis, 1928, (*non* Brady, 1879), Cushman Lab. Foram. Res., Contr. vol. 4, p. 86, pl. 12, fig. 3; and for same reference in: Cushman, 1932, U. S. Nat. Mus., Proc., vol. 80, Art, 14, p. 7, pl. 1, fig. 14.

*Karreriella lalickeri* Cushman, Cushman Lab. Foram. Res., Spec. Publ. No. 16, p. 5, pl. 1, figs. 6, 7. Upper Eocene, Alabama.

*Lagena flexa* Cushman and Gray, Cushman Lab. Foram. Res., Contr. vol. 22. p. 68, pl. 12, figs. 18–21. Pliocene (*recte* Pleistocene), California.

——— *laevis* (Montagu, 1803) var. *baggi* Cushman and Gray, *ibid.*, Spec. Publ. No. 19, p. 18, pl. 3, figs. 26, 27. Pliocene, California. For: *Lagena laevis* Bagg, 1912 (*non* Montagu, 1803) U. S. Geol. Surv. Bull. 513, p. 48, pl. 13, figs. 5–8 (*nec* pl. 13, figs. 10, 11); *nec* pl. 14, figs. 23, 24.) Pliocene (*recte* Pleistocene), California.

——— *pliocenica* Cushman and Gray, *ibid.*, vol. 22, p. 68, pl. 12, figs. 22–25. Pliocene (*recte* Pleistocene), California.

——— ——— ——— ——— var. *discrepans* Cushman and Gray, *ibid.*, Spec. Publ. No. 19, p. 19, pl. 3, figs. 35–38. Pliocene (*recte* Pleistocene), California.

——— ——— ——— ——— var. *timmsana* Cushman and Gray, *ibid.*, vol. 22, p. 68, pl. 12, figs. 15–17. Pliocene (*recte* Pleistocene), California.

——— *submagnifica* Cushman and Gray, *ibid.*, Spec. Publ. No. 19, p. 22, pl. 4, figs. 12–15. Pliocene (*recte* Pleistocene), California.

——— *sulcata* (Walker and Boys, 1798) var. *laevicostata* Cushman and Gray, *ibid.*, vol. 22, p. 68, pl. 12, figs. 13, 14. Pliocene (*recte* Pleistocene), California.

*Lamarckina byramensis* Cushman and Todd, *ibid.*, vol. 22, p. 98, pl. 16, figs. 12, 13. Oligocene, Byram Marl, Mississippi.

——— *hemiglobosa* ten Dam, Soc Géol. France, Bull., (5), vol. 16, p. 16, text fig. 7. Albian, Holland (published February 1947). For: *Discorbina pileolus* Chapman, 1896 (*non* d'Orbigny, 1839), Jour. R. Micr. Soc. London, (2), vol. 16, p. 591, pl. 13, fig. 14.

*Lepidocyclina crucifera* Mohler, Eclog. geol. Helv., vol. 39, No. 2, (published July 31, 1947), p. 103, text fig. 2. Burdigalian, E. Borneo.

*Lenticulina mariae* Schijfsma, Mededeel. Geol Stichting Haarlem, ser. C, vol. V, No. 7, p. 56, pl. 3, fig. 9. Upper Cretaceous, Holland.

——— *multinodosa* Schijfsma, *ibid.*, ser. C, vol. V, No. 7, p. 57, pl. 3, fig. 10. Upper Cretaceous, Holland. For: *Cristellaria nodosa* Chapman, 1896, (*non* Reuss, 1863), Jour. R. Micr. Soc. London, (2), vol. 16, p. 4, pl. 1, fig. 5.

——— *ordinaris* Schijfsma, *ibid.*, ser. C., vol. V, No. 7, p. 58, pl. 3, fig. 11. Upper Cretaceous, Holland. For: *Robulus münsteri* Cushman, 1941, (*non* Roemer, 1839), Cushman Lab. Foram. Res., Contr. vol. 17, p. 58, pl. 15, fig. 6; for same reference in Cushman, and Deaderick, 1942, *ibid.*, Contr. vol. 18, p. 56, pl. 10, figs. 10–13; and for same reference in: Cushman, 1944, *ibid.*, Contr. vol. 20, p. 85, pl. 13, fig. 7.

*Lingulina aeolia* Loeblich and Tappan, Jour. Paleontology, vol .20, p. 253, pl. 36, figs. 21, 22. Lower Cretaceous, Texas.

——— *praelonga* ten Dam, *ibid.*, vol. 20, p. 576, pl. 88, fig. 12. Neocomian, Holland. For: *Frondicularia loryi* Eichenberg, 1935, (*non* Berthelin, 1880), Jahresber. 26. Niedersachs. Geol. Ver., p. 179, pl. 11, fig. 1.

*Loxostomum limbatum* (Brady, 1881) var. *striatum* Germeraad, in Rutten and Hotz, Geol., Petrogr. and Paleont. Results, Ceram, (3), Geol. No. 2, p. 68, pl. 3, fig. 19.

——— *trinitatensis* Cushman and H. H. Renz, Cushman Lab. Foram. Res., Spec. Publ. No. 18, p. 39, pl. 6, figs. 24, 25. Uppermost Cretaceous, Trinidad, British West Indies.

*Marginulina hechti* ten Dam, Jour. Paleontology, vol. 20, p. 576, pl. 88, figs. 13, 14. Neocomian, Holland. For: *Marginulina linearis* Eichenberg, 1933 (*non* Reuss, 1863), 25. Jahresber. Nieder-

sachs. Geol. Ver., p. 161, pl. 11, figs. 2 and 7.

——— *lalickeri* Cushman, Cushman Lab. Foram. Res., Spec. Publ. No. 16, p. 11, pl. 3, fig. 1. Upper Eocene, Alabama.

——— *sestrona* Loeblich and Tappan, Jour. Paleontology, vol. 20, p. 252, pl. 36, figs. 17–19. Lower Cretaceous, Texas.

*Marssonella keijzeri* van Bellen, Proefschrift (Thesis), Univ. Utrecht, p. 30, pl. 11, figs. 3–5. Middle Eocene, Holland.

——— *oxycona* (Reuss, 1860), var. *trinitatensis* Cushman and H. H. Renz, Cushman Lab. Foram. Res., Spec. Publ. No. 18, p. 22, pl. 2, fig. 29. Uppermost Cretaceous, Trinidad, British West Indies, For: *Gaudryina oxycona* Cushman and Jarvis, 1932 (*non* Reuss, 1860), U. S. Nat. Mus., Proc., vol. 80, Art, 14, p. 18, pl. 5, figs. 1, 2.

*Massilina pulchra* Cushman and Gray, *ibid.*, Contr. vol. 22, p. 65, pl. 12, fig. 1. Pliocene (*recte* Pleistocene), California.

*Meandrospira* gen. nov. Loeblich and Tappan, Jour. Paleontology, vol. 20, p. 248. Family: Ophthalmidiidae; subfamily: Cornuspirinae. Genotype: *Meandrospira washitensis* Loeblich and Tappan, 1946, *ut infra*. Lower Cretaceous.

——— *washitensis* Loeblich and Tappan, *ibid.*, vol. 20, p. 248, pl. 36, figs. 4–7. Lower Cretaceous, Texas.

*Neofusulinella montis* Thompson and Wheeler, Geol. Soc. America, Mem. No. 17, p. 26, pl. 2, figs. 5–9, Permian, North California.

——— *occidentalis* Thompson and Wheeler, *ibid.*, Mem. No. 17, p. 25, pl. 3, figs. 1–4. Permian, North California.

*Neolepidina* Brönnimann, nom. nov., Eclog. geol. Helvet., vol. 39, No. 2, (published July 31, 1947), p. 377. New subgenus of *Lepidocyclina* Gümbel, 1868. New name for: *Pliolepidina* H. Douville, 1915. Subgenotype: *Lepidocyclina* (*Pliolepidina*) *tobleri* H. Douville, 1917. Upper Eocene, Tropical America; Mediterranean Region.

*Nodosarella cuneata* Loeblich and Tappan, Jour. Paleontology, vol. 20, p. 255, pl. 37, fig. 9. Lower Cretaceous, Texas.

——— *hedbergi* Cushman and H. H. Renz, Cushman Lab. Foram. Res., Spec. Publ. No. 18, p. 42, pl. 6, figs. 30, 33. Uppermost Cretaceous, Trinidad, British West Indies.

——— *kugleri* Cushman and H. H. Renz, *ibid.*, Spec. Publ. No. 18, p. 42 pl. 7, fig. 1. Uppermost Cretaceous, Trinidad, British West Indies.

——— *paleocenica* Cushman and Todd, *ibid.*, Contr. Vol. 22, p. 60, pl. 10, fig. 23. Paleocene, Arkansas.

*Nodosaria praecatesbyi* Cushman and Todd, *ibid.*, Contr. vol. 22, p. 85, pl. 14, figs. 28, 29. Oligocene, Byram Marl, Mississippi. For: *Nodosaria sp.* Cushman, 1922, U. S. Geol. Surv., Prof. Pap. 129-F, p. 130, pl. 30, fig. 5; for: *Nodosaria* cf. *catesbyi* Cushman and McGlamery, 1938 (*non* d'Orbigny, 1839), *ibid.*, Prof. Pap. 189–D, p. 105, pl. 24, fig. 10; and for same references in: Cushman and McGlamery, 1942, *ibid.*, Prof. Pap. 197–B, p. 67, pl. 4, figs. 13–19.

——— *rugosa* ten Dam, Jour. Paleontology, vol. 20, p. 575, pl. 88, fig. 7. Neocomian, Holland. For: *Dentalina* sp. Eichenberg, 1935, 26. Jahresber. Niedersachs. Geol. Ver., p. 166, pl. 12, fig. 3 and 4. (Note: The species name is preoccupied by d'Orbigny, 1839, in de la Sagra, Hist. Phys. etc. Cuba, Foraminiferes, vol. 8, p. 13, pl. 1, figs. 1, 2.)

*Nonion alabamense* Cushman and Todd, Cushman Lab. Foram. Res., Contr., vol. 22, p. 88, pl. 15, figs. 9, 10. Oligocene, Byram Marl, Mississippi.

——— *geleense* van Bellen, Proefschrift (Thesis) Univ. Utrecht, p. 42, pl. 3, figs. 22–25. Middle Eocene, Holland.

——— *multisuturatum* van Bellen, *ibid.*, p. 44, pl. 4, figs. 3–6. Middle Eocene, Holland.

——— *ornatum* van Bellen, *ibid.*, p. 44, pl. 4, figs. 7–10 (error for 1–10), Middle Eocene, Holland. (Note: Since this species name is preoccupied by *Nonionina ornata* Costa, 1856, Atti Accad. Pont. Napoli, vol. 7, fasc. 2, p. 203, pl. 17, fig. 17, van Bellen has changed his name into *Nonion thalmanni* nom. nov. *ut infra*.)

——— *punkae* Germeraad, in Rutten and Hotz, Geol., Petrogr. and Palaeont. Results, Ceram, (3), Geol. No. 2, p. 66, pl. 1, figs. 31, 32. Pliocene, Ceram.

——— *thalmanni* van Bellen, nom. nov., Cushman Lab. Foram. Res., Contr. vol. 22, p. 121. New name for: *Nonion ornatum* van Bellen, 1946, *ut supra*, (*non* Costa, 1856). Middle Eocene, Holland.

*Nonionella hantkeni* (Cushman and Applin, 1926) var, *byramensis* Cushman and Todd, *ibid.*, Contr. vol. 22, p. 89, pl. 15, figs. 11, 12. Oligocene, Byram Marl, Mississippi.

*Nummulites senonicus* Pérébaskine, nom. nov., Soc. géol. France, Comptes-rendus, fasc. 14, p. 297. New name for: *Nummulites cretaceus* Pérébaskine, 1942 (*non* Fraas, 1867). Bull. Soc. Geol. France, (5), vol. 12, p. 119, text figs. 1–7. Upper Cretaceous, France.

*Ophthalmidium amplectens* Loeblich and Tappan, Jour. Paleontology, vol. 20, p. 250, pl. 36, fig. 14. Lower Cretaceous, Texas.

——— *macfadyeni* Wood and Barnard, Geol. Soc. London, Quart. Jour., vol. 102, pt. 2, p. 92, pl. 9, fig .f. Lower Liassic, England.

——— *northamptonensis* Wood and Barnard, *ibid.*, vol. 102, pt. 2, p. 88, pl. 8, fig. c. (no age or locality given). For: *Ophthalmidium carinatum* Haeusler, 1887, (*non* Kübler and Zwingli, 1866), N. Jahrb. f. Min. etc., pl. 2, figs. 39, 40, 43–45; and for: *Ophthalmidium birmenstorfensis* Haeusler, 1887, (*non* Kübler and Zwingli, 1870), *ibid.*, pl. 2, fig. 42.

——— ——— ——— ——— var. *asymmetrica* Wood and Barnard cline *circularis* Wood and Barnard, *ibid.*, vol. 102, pt. 2, p. 106, pl. 7, fig. o. (No age or locality cited).

*Ophthalmina scariosa* Loeblich and Tappan, Jour. Paleontology, vol. 20, p. 251, pl. 36, figs. 15, 16. Lower Cretaceous, Texas. For:

*Ophthalmidium adhaerens* Tappan, 1943, Jour. Paleontology, vol. 17, p. 491, pl. 78, fig. 35 (*nec* fig. 34).

*Palmerinella thalmanni* Stainforth and Stevenson, Jour. Paleontology, vol. 20, p. 563, pl. 86, figs. 7–10. Basal Miocene, Ecuador.

*Parafusulina alaskensis* Dunbar, Amer. Mus. Novitates, No. 1325, p. 1, text figs. 1–9. Artinskian (Permian), Kuiu Island, Alaska.

——— *nosonensis* Thompson and Wheeler, Geol. Soc. America, Mem. No. 17, p. 33, pl. 7, figs. 1–12. Permian, North California.

——— *virga* Thompson and Wheeler, *ibid.*, Mem. No. 17, p. 32, pl. 6, figs. 1–3; pl. 9, figs. 1–7. Permian, North California.

*?Parafusulina calx* Thompson and Wheeler, *ibid.*, Mem. No. 17, p. 29, pl. 4, figs. 4–6; pl. 6, figs. 4, 5. Permian, North California.

*?——— turgida* Thompson and Wheeler, *ibid.*, Mem. No. 17, p. 30, pl. 4, figs. 4–6; pl. 6, figs. 1–6. Permian, North California.

[*Parrella mariei* van Bellen, Proefschrift (Thesis), Univ. Utrecht, p. 70, pl. 10, figs. 1–6. Middle Eocene, Holland. (Note: This species was first named *Pulvinulinella mariei* by van Bellen, but has been changed, on the errata slip on p. 145 to *Parella mariei* van Bellen.).]

*Pithonella caucasica* Keller, Soc. Natural. Moscou, Bull., new series, vol. 51, sect. géol. vol. 21, p. 95, pl. 3, fig. 2, Upper Cretaceous, Caucasus.

*Pithonellidae* fam. nov. Keller, *ibid.*, Bull. vol. 51, sect. géol. vol. 21, p. 94. (New family erected for single-chambered forms with calcareous wall including: *Calpionella* Lorentz, *Pithonella* Lorentz, and *Sphaerella* Keller, 1946, *ut infra*.) Upper Cretaceous.

*Planomalina* gen. nov. Loeblich and Tappan, Jour. Paleontology, vol. 20, p. 257. Family: Anomalinidae; subfamily: Anomalininae. Genotype: *Planomalina apsidostroba* Loeblich and Tappan, 1946, *ut infra*. Lower Cretaceous.

——— *apsidostroba* Loeblich and Tappan, *ibid.*, vol. 20, p. 258, pl. 37, figs. 22, 23. Lower Cretaceous, Texas.

*Planularia guttata* ten Dam, *ibid.*, vol. 20, p. 574, pl. 88, fig. 2. Neocomian, Holland.

*Planulina wheeleri* Stainforth and Stevenson, *ibid.*, vol. 20, p. 562, pl. 87, figs. 4–6. Upper Oligocene, Ecuador.

*Polychasmina* gen. nov. Loeblich and Tappan, *ibid.*, vol. 20, p. 242. Family: Reophacidae; subfamily: Reophacinae. Genotype: *Polychasmina pawpawensis* Loeblich and Tappan, 1946, *ut infra*. Lower Cretaceous.

——— *pawpawensis* Loeblich and Tappan, *ibid.*, vol. 20, p. 242, pl. 36, fig. 2; text fig. 2. Lower Cretaceous, Texas.

*Polydiexodina afghanensis* Thompson, 1946, *ibid.*, vol. 20, p. 150, pl. 24, figs. 1–6; pl. 26, figs. 1–7. Permian, North Afghanistan. For: (*?*) *Fusulina elongata* Hayden, 1909, Rec. Geol. Surv. India, vol. 28, p. 247, pl. 17, figs. 3–5; pl. 20, figs. 1–12.

*Polysegmentina* gen. nov. Cushman, Cushman Lab. Foram. Res., Contr. vol. 22, p. 1. Family: Ophthalmidiidae. Genotype: *Hauerina cirrinata* Brady, 1881, Quart. Jour. Micr. Sci., London, vol. 21, p. 17; figured in Brady, 1884, Rept. Voyage Challenger, Zool., vol. 9, p. 191, pl. 11, figs. 14–16. Recent, Pacific.

*Pseudoclavulina eggeri* Cushman, 1937, var. *maxima* Colom, Inst. Geol. Min. Espana, Notas y Commun., No. 16, p. 150, pl. 1, fig. 2. Senonian, Pyrenees, Spain.

*Pseudoglandulina turbinata* Detling, Jour. Paleontology, vol. 20, p. 354, pl. 48, fig. 8. Eocene-Oligocene, Oregon, U. S. A.

*Pseudopolymorphinoides* gen. nov. van Bellen Proefschrift (Thesis), Univ. Utrecht, p. 41. Family: Polymorphinidae. Genotype: *Pseudopolymorphinoides limburgensis* van Bellen, 1946, *ut infra*. Middle Eocene.

——— *limburgensis* van Bellen, *ibid.*, p. 41, pl. 3, figs. 16–19. Middle Eocene, Holland.

*Pseudoschwagerina arta* Thompson and Hazzard, Geol. Soc. America. Mem. No. 17, p. 49, pl. 18, figs. 1–3. Permian, South California.

——— *d'orbignyi* Dunbar and Newell, Amer. Journ. Science, vol. 244, p. 472, pl. 6, figs. 1–9. Permian, Bolivia.

——— *koslowskii* Dunbar and Newell, *ibid.*, vol. 244, p. 470, pl. 5, figs. 1–7. Permian, Bolivia.

——— *roeseleri* Thompson and Hazzard, Geol. Soc. America, Mem. No. 17, p. 47, pl. 17, figs. 4–6; pl. 18, fig. 4. Permian, South California.

——— *uber* Thompson and Hazzard, *ibid.*, Mem. No. 17, p. 48, pl. 14, figs. 10, 11; pl. 17, figs. 1–3. Permian, South California.

*Pseudotextularia koslovi* Keller, Soc. Natural Moscou, Bull., new series, vol. 51, sect. géol. vol. 21, p. 92, pl. 3, fig. 1. Upper Cretaceous, Caucasus.

*?Pulleniatina semi-involuta* Germeraad, in Rutten and Hotz, Geol., Petrogr. and Palaeont. Results, Ceram, (3), Geol. No. 2, p. 72, pl. 4, figs. 16–18. Pliocene, Ceram.

*Pulvinulinella culter* (Parker and Jones, 1865) var. *midwayana* Cushman and Todd, Cushman Lab. Foram. Res., Contr., vol. 22, p. 63, pl. 11, fig. 12. Paleocene, Arkansas. For: *Pulvinulinella culter* (Parker and Jones) var. *mexicana* Cushman, 1940, (*non* Cole, 1927), *ibid.*, Contr. Vol. 16, p. 72, pl. 12, fig. 12.

*Pyrgo byramensis* Cushman and Todd, *ibid.*, Contr. vol. 22, p. 83, pl. 14, figs. 18, 19. Oligocene, Byram Marl, Mississippi.

——— *monroei* Cushman and Todd, *ibid.*, Contr. vol. 22, p. 84, pl. 14, figs. 20, 21. Oligocene (Byram marl), Mississippi.

*Quadratina* gen. nov. ten Dam, Soc. géol. France, Bull., (5) vol. 16, p. 65 (published February 1947). Family: Lagenidae; subfamily: Nodosariinae. Genotype: *Quadratina depressula* ten Dam, 1946, *ut infra*. Lower Cretaceous.

——— *depressula* ten Dam, *ibid.*, Bull., (5), vol. 16, p. 66, text fig. 1 (published February 1947). Hauterivian, Holland.

*Quinqueloculina aeschria* Loeblich and Tappan, Jour. Paleontology, vol. 20, p. 246, pl. 35, figs. 14–17. Lower Cretaceous, Texas.

——— *crassa* d'Orbigny, 1850, var. *macerata* Cushman and Todd, Cushman Lab. Foram. Res., Contr. vol. 22, p. 79, pl. 14, figs. 3, 4.

Oligocene, Byram Marl, Mississippi. For: *Quinqueloculina crassa* Cushman, 1922, (*non* d'Orbigny, 1850), U. S. Geol. Surv., Prof. Pap. 129-E, p. 101, pl. 27, figs. 1, 2; for same reference in: Cushman and McGlamery, 1938, *ibid.*, Prof. Pap. 189-D, p. 104, pl. 24, fig. 4; and for same reference in: Cushman and Ellisor, 1945, Jour. Paleontology, vol. 19, p. 550, pl. 72, fig. 4.

——— *granulo-costata* Germeraad, in Rutten and Hotz, Geol., Petrogr. and Palaeont. Results, Ceram, (3), Geol. No. 2, p. 63, Not figured. Recent, Ceram. For: *Miliolina linneana* Brady, 1884 (*non* d'Orbigny, 1839), Rept. Voyage Challenger, Zool., vol. 9, p. 174, pl. 6. figs. 15–20.

——— *lirellangula* Loeblich and Tappan, Jour. Paleontology, vol. 20, p. 247, pl. 35, figs. 18, 19. Lower Cretaceous, Texas.

———*mcglameryae* Cushman and Todd, Cushman Lab. Foram. Res., Contr. vol. 22, p. 80, pl. 13, figs. 22, 23. Oligocene, Byram Marl, Mississippi. For: *Quinqueloculina* sp. Cushman and McGlamery, 1942, U. S. Geol. Surv. Prof. Pap. 197-B, p. 66, pl. 4, fig. 2.

———*monroei* Cushman and Todd, *ibid.*, Contr. vol. 22, p. 79, pl. 14, figs. 1, 2. Oligocene, Byram Marl, Mississippi. For: *Quinqueloculina bicostata* d'Orbigny *var.* Cushman, 1922, U. S. Geol. Surv. Prof. Pap. 129-E, p. 102, pl. 26, figs. 2–4.

———*sabella* Loeblich and Tappan, Jour. Paleontology, vol. 20, pl. 247, pl. 35, fig. 20. Lower Cretaceous, Texas.

———*transverse-striata* Germeraad, in Rutten and Hotz, Geol., Petrogr. and Palaeont. Results, Ceram, (3), Geol. No. 2, p. 64, pl. 1, fig 12–14. Recent, Ceram. (Note: This species is preoccupied by van Soest, 1942, Thesis Univ. Utrecht, p. 25, pl. 1, figs. 5, 6.)

*Raadshoovenia* gen. nov. van den Bold, Proefschrift (Thesis) Univ. Utrecht, p. 123. Family: Miliolidae, Genotype: *Raadshoovenia guatemalensis* van den Bold, 1946, *ut infra*. Lower Eocene.

———*guatemalensis* van den Bold, *ibid.*, p. 123, pl. 18, fig. 3. Lower Eocene, Guatemala.

*Ramulina abscissa* Loeblich and Tappan, Jour. Paleontology, vol. 20, p. 254, pl. 37, figs. 7, 8. Lower Cretaceous, Texas

*Reophax incompta* Loeblich and Tappan, *ibid.*, vol. 20, p. 242, text fig. 1. Lower Cretaceous, Texas.

———*pepperensis* Loeblich, *ibid.*, vol. 20, p. 133, pl. 22, fig. 1. Upper Cretaceous, Texas.

*Reussella byramensis* Cushman and Todd, Cushman Lab. Foram. Res., Contr. vol. 22, p. 94, pl. 16, figs. 4, 5. Oligocene, Byram Marl, Mississippi.

———*oligocenica* Cushman and Todd, *ibid.*, Contr. vol. 22, p. 94, pl. 16, figs. 6, 7. Oligocene, Byram Marl, Mississippi.

*Rhapidionina limbata* (*recte Rhapydionina*) van den Bold, Proefschrift (Thesis), Univ. Utrecht, p. 123, pl. 18, fig. 10. Lower Eocene, Guatemala. For: ? *Rhapydionina* sp. Keijzer, 1945, Proefschrift (Thesis), Univ. Utrecht, p. 201, pl. 11, fig. 9.

*Robulus alto-costatus* Germeraad, in Rutten and Hotz, Geol., Petrogr. and Palaeont. Results, (3), Geol. No. 2, p. 65, pl. 1, figs. 20, 21. Pliocene, Ceram. [Note: The species-name is preoccupied by the following varietal name: *Robulus mexicanus* (Cushman, 1925) var. *alticostatus* Cushman and Barksdale, 1930, Contr. Geol. Dept. Stanford Univ., vol. 1, p. 63, pl. 11, figs. 4–7].

———*arkansana* Cushman and Todd, Cushman Lab. Foram. Res., Contr. vol. 22, p. 48, pl. 7, fig. 14. Paleocene, Arkansas.

———*coaledensis* Detling, Jour. Paleontology, vol. 20, p. 353, pl. 48, fig. 1. Eocene, Oregon, U. S. A.

———*inusitatus* Cushman, Cushman Lab. Foram. Res., Spec. Publ. No. 16, p. 7, pl. 2, figs. 1–7. Eocene, Alabama. For: *Robulus gutticostatus* Cushman, 1935, (*non* Gümbel, 1868), U. S. Geol. Surv., Prof. Pap. 181, p. 15, pl. 5, figs. 1, 2.; and for: *Robulus gutticostatus* (Gümbel, 1868) var. *cocoaensis* Cushman, 1935, *ibid.*, Prof. Pap. 181, pl. 5, fig. 3 (*nec* fig. 4.)

———*pseudocassis* Cushman and Gray, *ibid.*, Contr., vol. 22, p. 65, pl. 12, fig. 2. Pliocene (*recte* Pleistocene), California.

———*seranensis* Germeraad, in Rutten and Hotz Geol., Petrogr. and Palaeont. Results, Ceram. (3), Geol. No. 2, p. 65, pl. 2, figs. 5, 6. Pliocene, Ceram.

———*tumido-costatus* (Cushman, 1917) var. *punkae* Germeraad, *ibid.*, Geol. No. 2, p. 66, pl. 2, figs. 7, 8. Pliocene, Ceram.

———*wilcoxensis* Cushman and Ponton, 1932, var. *dissentia* Cushman and Todd, Cushman Lab. Foram. Res., Contr. vol. 22, p. 48, pl. 7, fig. 12. Paleocene, Arkansas.

*Rotalia bundensis* van Bellen, Proefschrift (Thesis), Univ. Utrecht, p. 61, pl. 8, figs. 1–4. Middle Eocene, Holland.

———*margaritifera* (Brady, 1881) var. *polysepta* Germeraad, in Rutten and Hotz. Geol., Petrogr. and Palaeont. Results, Ceram, (3), Geol. No. 2, p. 70, pl. 2, figs. 18, 19. Pliocene, Ceram.

———*pseudomarginata* van Bellen, nom. nov. Cushman Lab. Foram. Res., Contr. vol. 22, p. 123. Middle Eocene, Holland. New name for *Rotalia terquemi* van Bellen, 1946, *ut infra*, (*non* d'Orbigny, 1850).

———*reverso-fimbriata* Germeraad, in Rutten and Hotz, Geol., Petrogr. and Palaeont. Results, Ceram, (3), Geol. No. 2, p. 70, pl. 2, figs. 20–22. Pliocene, Ceram.

———*rolshauseni* Cushman and Bermudez, Cushman Lab. Foram. Res., Contr. vol. 22, p. 119, pl. 19, figs. 11–13. Recent, Gulf of Mexico, off Rio Grande, 83 feet depth.

———*terquemi* van Bellen, Proefschrift (Thesis), Univ. Utrecht, p. 63. For: *Rotalia marginata* Terquem, 1882, (*non* d'Orbigny, 1826), Mem. Soc. géol. France, (3), vol. 2, p. 80, pl. 16, fig. 5. Middle Eocene, Holland. [Note: On account of homonymy with *Rotalia* (*Rotalina*) *terquiemi* d'Orbigny, 1850, Prodrome vol. 1, p. 242, van

Bellen has changed his name to *Rotalia pseudomarginata* nom. nov. *ut supra*.]

*Ruttenia geelensis* van Bellen, *ibid.*, p. 76, pl. 11, figs. 13–15. Middle Eocene, Holland.

*Rzehakina epigona* (Rzehak, 1895) var. *minima* Cushman and H. H. Renz, Cushman Lab. Foram. Res., Spec. Publ. No. 18, p. 24, pl. 3, fig. 5. Uppermost Cretaceous, Trinidad, British West Indies.

*Saracenaria frankei* ten Dam, Jour. Paleontology, vol. 20, p. 573, pl. 88, fig. 1. Neocomian, Holland. For: *Saracenaria italica* Eichenberg, 1935 (*non* Defrance, 1824), 26. Jahresber. Niedersächs. Geol. Ver., p. 158, pl. 11, fig. 21.

*Schubertella masoni* Thompson and Hazzard, Geol. Soc. America, Mem. No. 17, p. 41, pl. 13, figs. 7–10. Permian, South California.

*Schwagerina aculeata* Thompson and Hazzard, *ibid.*, Mem. No. 17, pl. 45, pl. 12, figs. 1–8. Permian, South California.

———— ———— ———— ————var. *plena* Thompson and Hazzard, *ibid.*, Mem. No. 17, p. 46, pl. 13, figs. 1–6. Permian, South California.

————*ahlfeldi* Dunbar and Newell, Amer. Jour. Science, vol. 244, p. 462, pl. 3, figs. 1–10. Permian, Bolivia.

————*fax* Thompson and Wheeler, Geol. Soc. America, Mem. No. 17, p. 27, pl. 1, figs. 1–4. Permian, North California.

————*furoni* Thompson, Jour. Paleontology, vol. 20, p. 147, pl. 23, figs. 1–4; pl. 24, figs. 7–10. Permian, North Afghanistan. For: *Fusulina sp.* Furon, 1927, L'Hindou-Kouch et le Kaboulistan, p. 64, pl. 3.

————*modica* Thompson and Hazzard, Geol. Soc. America, Mem. No. 17, p. 44, pl. 11, figs. 1–7. Permian, South California.

————*muñanensis* Dunbar and Newell, Amer. Jour. Science, vol. 244, p. p. 467, pl. 11, figs. 7–13. Permian form, reworked in Cretaceous conglomerates above the Permian section, Peru.

————*providens* Thompson and Hazzard. *ibid.*, Mem. no. 17, p. 43, pl. 14, figs. 1–9. Permian, South California.

————*steinmanni* Dunbar and Newell, Amer. Jour. Science, vol. 244, p. 460, pl. 2, figs. 1–10. Permian, Bolivia.

————*? multispira* Thompson and Hazzard, Geol. Soc. America, Mem. No. 17, p. 46, pl. 15, figs. 1–4. Permian, South California.

————(*?*) *patens* Dunbar and Newell, Amer. Jour. Science, vol. 244, p. 464, pl. 4, figs. 1–8; pl. 8, figs. 11, 12. Permian, Bolivia. For: *Schwagerina aff. laxissima* Thompson, 1953, Jour. Paleontology, vol. 17, p. 204, pl. 33.

*Sigmoilina chapmani* Cushman, Cushman Lab. Foram. Res., Contr. vol. 22, p. 31, pl. 5, figs. 7–9. Oligocene, Victoria, Australia. For: *Sigmoicelata* Chapman, 1907 (*non* Costa, 1855 (1857), Jour. Linn. Soc. London, Zool., vol. 30, p. 21, pl. 2, fig. 41.

————*flintii* Cushman, *ibid.*, Contr. vol. 22, p. 44, pl. 6, figs. 35–39. Recent, Albatross Station D-2641. 60 fathoms.

————*miocenica* Cushman, *ibid.*, Contr. vol. 22, p. 33, pl. 5, figs. 19–22. Miocene, Florida. For: *Sigmoilina tenuis* Cushman, 1929, (*non* Czijzek 1847), Cushman Lab. Foram. Res., Contr., vol. 5, p. 81, pl. 12, figs. 12–14; for same reference in: Cushman, 1930, Florida State Geol. Surv., Bull. No. 4, p. 22, pl. 2, fig. 8; and for same reference in: Cushman and Cahill, 1933, U. S. Geol. Surv., Prof. Pap. 175-A, p. 11, pl. 3, fig. 1.

————*oligocenica* Cushman, *ibid.*, Contr. vol. 22, p. 31, pl. 5, fig. 6. Lower Oligocene, Mississippi. For: *Sigmoilina tenuis* Nuttall, 1932, (non Czijzek, 1947), Jour. Paleontology, vol. 6, p. 9, pl. 1, fig. 4; and for same reference in: Franklin, 1944, Jour. Paleontology, vol. 18, p. 308, pl. 65, fig. 5.

————*personata* Mohler, Eclog. geol. Helv., vol. 39. No. 2 (published July 31, 1947), p. 298, text fig. 1, Upper Eocene, S. E. Borneo.

————*porcellanea* Germeraad, in Rutten and Hotz, Geol., Petrogr. and Palaeont. Results, Ceram, (3), Geol. No. 2, p. 65, pl. 1, figs. 16, 17. Pliocene, Ceram.

————*sigmoidea* (Brady, 1884) var. *compressa* Cushman, Cushman Lab. Foram. Res., Contr., vol. 22, p. 32, pl. 5, figs. 10–12. Oligocene, Victoria, Australia. For: *Sigmoilina sigmoidea* Chapman, 1907, (*non* Brady, 1884). Jour. Linn. Soc. London, Zool., vol. 30, p. 20, pl. 2, fig. 40. (Note: On account of homonymy with *Sigmoilina tchokrakensis* Gherke 1983, var. *compressa* Gherke, 1938, Problems of Paleontology, Moscow, vol. 4, p. 312, pl. 3, figs. 4, 13, and 18, Cushman changed his name into: *Sigmoilina victoriensis* Cushman 1946, nom. nov. *ut infra*.)

————*victoriensis* Cushman, nom. nov., *ibid.*, Contr. vol. 22, p. 103. New name for: *Sigmoilina sigmoidea* (Brady, 1884) var. *compressa* Cushman, 1946, *ut supra*, (non Gherke, 1938).

*Siphogenerinoides bermudezi* Stone, Jour. Paleontology, vol. 20, p. 475, pl. 71, figs. 20–25. Upper Cretaceous, northwestern Peru.

———— ———— ————var. *peruviana* Stone, *ibid.*, vol. 20, p. 476, pl. 71, pp. 17–19. Upper Cretaceous, N. W. Peru.

————*landesi* Stone, *ibid.*, vol. 20, p. 476, pl. 72, figs. 13–17. Upper Cretaceous, N. W. Peru.

————*reticulata* Stone, *ibid.*, vol. 20, p. 476, pl. 72, figs. 18–25. Upper Cretaceous, N. W. Peru.

————*revoluta* Stone, *ibid.*, vol. 20, p. 477, pl. 72, figs. 1–7. Upper Cretaceous, N. W. Peru.

*Siphotextularia washitensis* Loeblich and Tappan, ibid., vol. 20, p. 245, pl. 35, figs. 9–11. Lower Cretaceous, Texas.

*Sphaerella* gen nov. Keller, Soc. Natural. Moscou, Bull., vol. 51, sect. geol. vol. 21, p. 95. Family: Pithonellidae Keller, 1946, *ut supra*. Genotype: *Lagena orbulinaria* de Lapparent, 1923, Leçons de Petrogr., p. 273, pl. 14, fig. 1. Upper Cretaceous. [Note: The genus name is preoccupied by Sommerfeldt, 1824, Magaz. Naturwiss. vol. 4, p. 252 (Prot.); by Conrad, 1838, Foss. Med. Tert. U. S., (1), p. 17 (Moll.); by Conrad, 1860, (non Conrad, 1838), Jour. Acad. Nat. Sci. Philadelphia, (2), vol. 4, p. 280 (Moll.), and by Gray, 1869, Ann. Mag. Nat. Hist., (4), vol. 3, p. 122 (Coel.).]

*Spiroloculina inopinata* Wood and Barnard, Geol. Soc. London, Quart. Jour., vol. 102, pt. 2, p. 93, pl. 10, fig. a. Upper Liassic, England. For: Species figures in Haeusler, 1887, N. Jahrb. f. Min. etc., pl. 6, fig. 37.)

———*ophionea* Loeblich and Tappan, Jour. Paleontology, vol. 20, p. 247, pl. 35, fig. 21. Lower Cretaceous, Texas.

*Spiroplectammina howei* Stuckey, *ibid.*, vol. 20, p. 164, pl. 29, figs. 8–10. Oligocene, Mississippi.

———*mississippiensis* (Cushman, 1922) var. *distincta* Cushman, Cushman Lab. Foram. Res., Spec. Publ. No. 16, p. 3, pl. 1, figs. 1, 2. Upper Eocene, Alabama.

*Stichocassidulina* gen. nov. Stone, Jour. Paleontology, vol. 20, p. 59. Family: Cassidulinidae; subfamily: Cassidulininae. Genotype: *Stichocassidulina thalmanni* Stone, 1946, *ut infra*. Upper Eocene.

———*thalmanni* Stone, *ibid.*, vol. 20, p. 60, text figs. 1, 2. Upper Eocene, N. W. Peru.

*Technitella archaeonitida* Stainforth and Stevenson, Jour. Paleontology, vol. 20, p. 561, pl. 86, figs. 1–3. Middle Oligocene, Ecuador.

*Terquemia* gen. nov. van Bellen, Proefschrift (Thesis), Univ. Utrecht, p. 86. No family stated. Genotype: *Rotalina lobata* Terquem, 1882, Mem. Soc. geol. France, (3), vol. 2, p. 63, pl. 4, fig. 10. Eocene. (Note: The genus name is preoccupied by Tate, 1868 for a genus in the Mollusca; by van Veen, 1932, for a genus in the Crustacea; and is a pseudo-homonym of *Terquemina* Galloway, 1933. The author has, therefore, changed his name into *Boldia* nom. nov. van Bellen, 1946, *ut supra*.)

*Textularia adkinsi* Loeblich, Jour. Paleontology, vol. 20, p. 138, pl. 22, fig. 13. Upper Cretaceous, Texas.

———*bundensis* van Bellen, Proefschrift (Thesis) Univ. Utrecht, p. 26, pl. 1, figs. 4–7. Middle Eocene, Holland.

———*lata* Germeraad, in Rutten and Hotz, Geol., Petrogr. and Palaeont. Results, Ceram, (3), Geol. No. 2, p. 62, pl. 1, figs. 4, 5. Pliocene, Ceram.

———*quadri-conula* Germeraad, *ibid.*, Geol. No. 2, p. 62, pl. 1, figs. 6, 7. Pliocene, Ceram.

———*seligi* Stuckey, Jour. Paleontology, vol. 20, p. 164, pl. 29, figs. 1–3. Oligocene, Mississippi.

*Textulariella trinitatensis* Cushman and H. H. Renz. Cushman Lab. Foram. Res., Spec. Publ. No. 18, p. 23, pl. 3, figs. 1–3. Uppermost Cretaceous Trinidad, British West Indies.

——— ——— ——— ———var. *subcylindrica* Cushman and H. H. Renz, *ibid.*, Spec. Publ. No. 18, p. 23, pl. 3, fig. 4. Uppermost Cretaceous, Trinidad, British West Indies.

*Triloculina byramensis* Cushman and Todd, Cushman Lab. Foram. Res., Contr. vol. 22, p. 83, pl. 14, figs. 16, 17. Oligocene, Mississippi.

———*meotica* Loeblich and Tappan, Jour. Paleontology, vol. 20, p. 247, pl. 36, figs. 1–3. Lower Cretaceous, Texas.

*Triplasia grosserugosa* ten Dam, *ibid.*, vol. 20, p. 571, pl. 87, fig. 6. Neocomian, Holland.

*Tristix acutangula* (Reuss, 1863) var. *lamellosa* ten Dam, *ibid.*, vol. 20, p. 575, pl. 88, fig. 9. Neocomian, Holland. For: *Rhabdogonium tricarinatum* Burrows, Sherborn, and Bailey, 1890, (*non* d'Orbigny, 1826), Jour. Roy. Micr. Soc. London, (2), vol. 10, p. 558. pl. 10, fig. 7.

———*crassa* ten Dam, *ibid.*, vol. 20, p. 576, pl. 88, fig. 10. Neocomian, Holland.

*Tritaxia compressa* Schijfsma, Mededeel. Geol. Stitchting Haarlem, series C, vol. V, No. 7, p. 33, pl. 1, fig. 5. Upper Cretaceous, Holland.

*Triticites boliviensis* Dunbar and Newell, Amer. Jour. Science, vol. 244, p. 482, pl. 9, figs. 1–11. Permian, Bolivia.

———*californicus* Thompson and Hazzard, Geol. Soc. America, Mem. No. 17, p. 42, pl. 10, figs. 10–14. Permian, South California.

———*nitens* Dunbar and Newell, Amer. Jour. Science, vol. 244, p. 483, pl. 9, figs. 12–16. Permian, Bolivia.

———*opimus* Dunbar and Newell, *ibid.*, vol. 244, p. 485, pl. 10, figs. 11–14. Permian, Peru.

———*patulus* Dunbar and Newell, *ibid.*, vol. 244, p. 478, pl. 10, figs. 1–10. Permian, Bolivia. For: *Fusulina peruana* Berry, 1933 (*non* Meyer, 1914), Pan-Amer. Geologist, vol. 59, p. 269, pl. 22.

———*titicacaensis* Dunbar and Newell, *ibid.*, vol. 244, p. 479, pl. 11, figs. 1–6. Permian, Bolivia.

*Trochammina exigua* Cushman and Applin, Cushman Lab. Foram. Res., Contr. vol. 22, p. 75, pl. 13, fig. 8. Basal Upper Cretaceous, Texas.

———*globigeriniformis* (Parker and Jones, 1865) var. *altiformis* Cushman and H. H. Renz, *ibid.*, Spec. Publ. No. 18, p. 24, pl. 3, figs. 7–11. Uppermost Cretaceous, Trinidad, British West Indies. For: *Trochammina globigeriniformis* Cushman and Jarvis, 1928, (*non* Parker and Jones, 1865), Contr. Cushman Lab. Foram. Res., vol. 4, p. 95, pl. 13, fig. 12; and for same reference in: Cushman and Jarvis, 1932, Proc. U. S. Nat. Mus., vol. 80, art. 14, p. 21, pl. 6, figs. 2–5.

———*rainwateri* Cushman and Applin, *ibid.*, Contr. vol. 22, p. 75, pl. 13, fig. 9. Basal Upper Cretaceous, Texas.

———*ruthven-murravi* Cushman and H. H. Renz, *ibid.*, Spec. Publ. No. 18, p. 24, pl. 3, fig. 13. Uppermost Cretaceous, Trinidad, British West Indies.

———*spiralis* Schijfsma, Mededeel. Geol. Stichting Haarlem, series C, vol. V, No. 7, p. 39, pl. 1, fig. 13. Upper Cretaceous, Holland.

———*undulosa* Schijfsma, *ibid.*, series C, vol. V. No. 7, p. 39, pl. 1, fig. 14. Uppermost Cretaceous, Holland.

———*wickendeni* Loeblich, Jour. Paleontology, vol. 20, p. 138, pl. 22, fig. 17. Upper Cretaceous, Texas.

*Trochamminoides coronus* Loeblich and Tappan, *ibid.*, vol. 20, p. 243, pl. 35, fig. 3. Lower Cretaceous, Texas.

*Vaginulina acricula* Loeblich and Tappan, Jour. Paleontology, vol. 20, p. 253, pl. 37, figs. 4–6. Lower Cretaceous, Texas.

———*advena* Cushman, 1923, var. *pauciloculata* Cushman and Gray, Cushman Lab. Foram.

Res., Spec. Publ. No. 19, p. 15, pl. 3, fig. 15. Pliocene (*recte* Pleistocene) California.

———*daini* Schijfsma, Mededeel. Geol. Stichting Haarlem, series C, vol. V, No. 7, p. 63, pl. 2, figs. 13, 14; pl. 10, fig. 13. Upper Cretaceous, Holland. For: *Vaginulina costulata* Beissel, 1891, (*non* Roemer, 1842), Abhandl. k. Preuss. Landes-Anst., n.s., vol. 3, p. 50, pl. 9, figs. 29–39; for: *Vaginulina elegans* d'Orbigny, 1826, var. *mexicana* Dain, 1934 (*non* Nuttall, 1932) Trans. Geol. Oil Inst. Leningrad-Moscow, series A, No. 43, pl. 2, fig. 21-b; and for: *Marginulina trilobata* Marie, 1941 (*non* d'Orbigny, 1840), Mem. Mus. Nation. Hist. Nat. Paris, n.s., vol. 12, pt. 1, pl. 13, fig. 158 (*nec* fig. 159).

———*leptoteicha* Loeblich and Tappan, Jour. Paleontology, vol. 20, p. 253, pl. 37, figs. 1–3. Lower Cretaceous, Texas.

———*pliocenica* Cushman and Gray, Cushman Lab. Foram. Res., Spec. Publ. No. 19, p. 15, pl. 3, fig. 14. Pliocene (*recte* Pleistocene), California.

———*subbadenensis* Cushman and Gray, *ibid.*, Contr. vol. 22, p. 66, pl. 12, figs. 6, 7. Pliocene (*recte* Pleistocene), California. For: *Vaginulina badenensis* Bagg, 1912, (*non* d'Orbigny, 1846), U. S. Geol. Surv., Bull. 513, p. 63, pl. 18, fig. 5; for: *Vaginulina legumen* Bagg, 1912 (*non* Linné, 1758), *ibid.*, Bull. 513, p. 63, pl. 18, figs. 6, 7; and for: *Vaginulina legumen* (Linné, 1758) var. *arquata* Bagg, 1912, *ibid.*, Bull. 513. pl. 64, pl. 18, fig. 8. (Note: The variety *arquata* is to be ascribed to Brady, 1884, not to d'Orbigny.)

——— ——— ——— ———var. *aculeata* Cushman and Gray, *ibid.*, Contr. vol. 22, p. 67, pl. 12, figs. 8–10. Pliocene, (*recte* Pleistocene) California.

——— ——— ——— ———var. *serrulata* Cushman and Gray, *ibid.*, Contr. vol. 22, p. 67, pl. 12, fig. 11. Pliocene (*recte* Pleistocene), California.

———*subrotunda* ten Dam, Jour. Paleontology, vol. 20, p. 574, pl. 88, fig. 3. Neocomian, Holland.

*Vaginulinopsis pachynota* ten Dam, Jour. Paleontology, vol. 20, p. 575, pl. 88, figs. 5, 6. Neocomian, Holland.

———*reticulosa* ten Dam, *ibid.*, vol. 20, p. 574, pl. 88, fig. 4. Neocomian, Holland.

*Valvulina germeraadi* van den Bold, Proefschrift (Thesis), Univ. Utrecht, p. 122, pl. 18, fig. 1. Lower Eocene, Guatemala, and British Honduras.

*Valvulineria punkae* Germeraad, in Rutten and Hotz, Geol., Petrograph. and Palaeont. Results, Ceram, (3), Geol. No. 2, p. 69, pl. 2, figs. 15–17. Pliocene, Ceram.

———*reussi* van Bellen, Proefschrift (Thesis), Univ. Utrecht, p. 56. For: *Anomalina involuta* (Reuss) in Cushman, 1931, Div. Geol. Tennessee, Bull. 41, p. 60, pl. 12, figs. 1–3. (*non Rotalina involuta* Reuss, 1851). Upper Cretaceous, Tennessee.

*Verneuilina chapmani* ten Dam, Jour. Paleontology, vol. 20, p. 562, pl. 87, fig. 8 (wrongly spelled "*Berneuilina*"). Neocomian, Holland. For: *Bulimina polystropha* Chapman, 1894, (*non* Reuss, 1846), Geol. Soc. London, Quart. Jour., vol. 50, p. 701, pl. 34, fig. 5.

———*perplexa* Loeblich, *ibid.*, vol. 20, p. 138, pl. 22, figs. 14–16. Upper Cretaceous, Texas.

———*tetraedra* Germeraad, in Rutten and Hotz, Geol. Petrogr, and Palaeontol. Results, Ceram, (3), Geol. No. 2, p. 62, pl. 2, figs. 1, 2. Pliocene, Ceram.

*Yangchienia haydeni* Thompson, Jour. Paleontology, vol. 20, p. 146, pl. 23, figs. 5–11. Permian, North Afghanistan.

## FORMS WITH NOMENCLATURA APERTA

(The numbers in *bold-face* type refer to the publications of the preceding Bibliography for 1946.)

*Angulogerina sp.* Germeraad, *102*, p. 69, pl. 3, fig. 23. Pliocene, Ceram.

*Articulina sp.* Cushman and Todd, *68*, p. 82, pl. 14, fig. 13. Oligocene, Mississippi.

*Asterigerina species* Schijfsma, *177*, p. 89, pl. 5, fig. 8. Upper Cretaceous, Holland.

*Bulimina sp. A* Detling, *81*, p. 356, pl. 50, fig. 1. Eocene, Oregon.

———*sp. B* Detling, *81*, p. 356, pl. 50, fig. 2. Eocene, Oregon.

———*nov. sp.* Germeraad, *102*, p. 68, pl. 3, fig. 14. Pliocene, Ceram.

*Cassidulina nov. sp.* Germeraad, *102*, p. 72, pl. 4, figs. 11, 12. Pliocene, Ceram.

———*sp.* Cushman, *56*, 36, pl. 7, fig. 12. Upper Eocene, Alabama.

*Chrysalogonium sp.* Cushman and Todd, *68*, p. 86, pl. 15, figs. 1, 2. Oligocene, Mississippi.

*Cibicides sp.* Cushman, *56*, 40, pl. 8, figs. 14, 15. Upper Eocene, Alabama.

———*sp.* (*mexicana* Nuttall?) Germeraad, *102*, p. 45, pl. 5, figs. 27–29. Eocene, Ceram.

———*sp.* (*punctulata* d'Orbigny?) Germeraad, *102*, p. 45, pl. 6, figs. 14–16. Eocene, Ceram.

*Citharina species* Schijfsma, *177*, 42, p. 2, fig. 22. Upper Cretaceous, Holland.

*Cymbaloporella sp.* Germeraad, *102*, p. 71, pl. 5, figs. 1, 2. Recent, Ceram.

*Cyclammina sp.* Detling, *81*, p. 352, pl. 46, fig. 2. Eocene, Oregon.

*Dentalina sp.* Cushman, *58*, p. 70, pl. 25, fig. 7. Upper Cretaceous, Trinidad. For: *Dentalina catenula* Cushman and Jarvis, 1932, (non Reuss, 1862), U. S. Nat. Mus., Proc., vol. 80, art. 14, p. 29, pl. 9, fig. 8.

———*sp.* Cushman and Todd, *68*, p. 85, pl. 14, fig. 27. Oligocene, Mississippi.

———*sp. A* Cushman, *56*, p. 14, pl. 3, figs. 16, 17. Upper Eocene, Alabama.

———*sp. A* Cushman and Todd, *67*, p. 51, pl. 8, fig. 10. Paleocene, Arkansas.

———*sp. B* Cushman and Todd, *67*, p. 51, pl. 8, figs. 15, 16. Paleocene, Arkansas.

———*sp. B* Cushman, *56*, p. 14, pl. 3, fig. 18. Upper Eocene, Alabama.

———*sp. C* Cushman and Todd, *67*, p. 52, pl. 8, fig. 17. Paleocene, Arkansas.

———*? sp.* Cushman and Gray, *64*, p. 14, pl. 3, figs. 5, 6. Pliocene, California.

*Ellipsonodosaria sp.* Cushman, *56*, p. 30, pl. 6, fig. 9. Upper Eocene, Alabama.
———*sp.* Cushman, *58*, p. 137, pl. 56, figs. *32*, Upper Cretaceous, Tennessee.
———*sp.* Cushman and Renz, *65*, p. 43, pl. 7. fig. 8. Upper Cretaceous, Trinidad.
*Entosolenia sp. A* Cushman and Renz, 65, p. 39, pl. 6, figs. 19, 20. Upper Cretaceous, Trinidad.
———*sp. B* Cushman and Renz, *65*, p. 39, pl. 6, fig. 21. Upper Cretaceous, Trinidad.
———*sp. C* Cushman and Renz, *65*, p. 39, pl. 6, fig. 22. Upper Cretaceous, Trinidad.
*Epistomina sp.* Germeraad, *102*, p. 70, pl. 2, fig. 26. Pliocene, Ceram.
*Eponides nov. sp.* Germeraad, *102*, p. 70, pl. 3, figs. 25–27. Pleistocene, Ceram.
———*sp.* Detling, *81*, p. 358, pl. 50, fig. 15. Eocene, Oregon.
*Flabellammina sp.* Cushman and Renz, *65*, p. 19, pl. 2, fig. 10. Upper Cretaceous, Trinidad.
*Frondicularia sp.* Cushman, *58*, p. 92, pl. 83, fig. 8. Upper Cretaceous, Trinidad. For: *Frondicularia gracilis?* Cushman and Jarvis, 1932, (*non* Franke), U. S. Nat. Mus., Proc., vol. 80, art. 14, p. 40, pl. 12, fig. 5.
———*sp. A* Cushman and Todd, *67*, p. 55, pl. 9, fig. 24. Paleocene, Arkansas.
*Gaudryina (Siphogaudryina) nov. sp.* Germeraad, *102*, p. 62, pl. 2, figs. 3, 4. Pleistocene, Ceram.
*Globulina species* Schijfsma, *177*, p. 65, pl. 7, fig. 1; text fig. 2. Upper Cretaceous, Holland.
*Goesella sp.* Colom, *42*, p. 153, pl. 1, fig. 4. Senonian, Spain.
*? Gordiospira sp.* Germeraad, *102*, p. 65, pl. 1, figs. 18, 19. Pliocene, Ceram.
*Guttulina sp.* van Bellen, *18*, p. 36, pl. 2, fig. 29. Middle Eocene, Holland.
———*species* Schijfsma, *177*, p. 67, pl. 7, fig. 5. Upper Cretaceous, Holland.
*Hyperammina ? sp.* Cushman, *58*, p. 15, pl. 1, fig. 14. Upper Cretaceous, Trinidad.
*Lagena sp. A* Cushman, *56*, p. 15, pl. 4, fig. 10. Upper Eocene, Alabama.
———*sp. A* Cushman and Todd, *67*, p. 56, pl. 9, fig. 27. Paleocene, Arkansas.
———*sp. B* Cushman, *56*, p. 18, pl. 4, fig. 11. Upper Eocene, Alabama.
*Laticarinina sp.* Germeraad, *102*, p. 73, pl. 5, figs. 8, 9. Pliocene, Ceram.
*Marginulina sp.* Cushman and Todd, *67*, p. 49, pl. 7, figs. 21, 22. Paleocene, Arkansas.
———*sp. A* Cushman, *58*, p. 64, pl. 22, fig. 23. Upper Cretaceous, Texas.
———*sp. A* Cushman, *56*, p. 12, pl. 3, fig. 4. Upper Eocene, Alabama.
———*sp. B* Cushman, *58*, p. 64, pl. 22, fig. 24. Upper Cretaceous, Texas.
———*sp. B* Cushman, *56*, p. 12, pl. 3, fig. 5. Upper Eocene, Alabama.
———*sp. C* Cushman, *58*, p. 64, pl. 22, figs. 25–27. Upper Cretaceous, Texas.
———*sp. C* Cushman, *56*, p. 12, pl. 3, fig. 6. Upper Eocene, Alabama.
———*species* Schijfsma, *177*, p. 59, pl. 4, fig. 2. Upper Cretaceous, Holland.
*Massilina sp.* Cushman, *58*, p. 49, pl. 14, figs. 16–18. Upper Cretaceous, Texas.
*? Nodosaria sp.* van Bellen, *18*, p. 34, pl. 2, fig. 24. Middle Eocene, Holland.
*Nonionella species* Schijfsma, *177*, p. 69, pl. 4, fig. 5. Upper Cretaceous, Holland.
*Operculina granulosa* (Leymerie, 1844) nov. var. Germeraad, *102*, p. 67, pl. 2, figs. 9, 10. Pliocene, Ceram. (Note: The author for *O. granulosa* is Michelotti, 1841, not Leymerie).
———*sp.* Germeraad, *102*, p. 67, pl. 2, figs. 11, 12. Pliocene, Ceram.
*Parafusulina sp.* Thompson and Hazzard, *221*, p. 50, pl. 13, fig. 11. Permian, California.
———*sp.* Thompson and Wheeler, *221*, p. 35, pl. 8, fig. 5. Permian, California.
*Patellina sp.* Cushman, *58*, p. 137, pl. 57, fig. 1. Upper Cretaceous, Tennessee.
*Peneroplis sp.* van den Bold, *24*, p. 123, pl. 18, fig. 4. Lower Eocene, Guatemala.
*Planularia sp.* Germeraad, *102*, p. 66, pl. 1, figs. 25, 26. Pliocene, Ceram.
———*sp. A* Cushman, *58*, p. 58, pl. 20, fig. 4. Upper Cretaceous, Texas.
———*sp. B* Cushman, *58*, p. 58, pl. 56, fig. 5. Upper Cretaceous, Colombia.
*Plectofrondicularia sp.* Germeraad, *102*, p. 67, pl. 3, figs. 7–12. Pliocene, Ceram.
———*sp. B* Detling, *81*, p. 356, pl. 49, fig. 4. Eocene-Oligocene, Oregon.
*Pleurostomella brevis* Schwager, 1866, *nov. var.* Germeraad, *102*, p. 69, pl. 3, fig. 24. Pliocene, Ceram.
*Polymorphina sp.* Cushman, *56*, p. 20, pl. 4, fig. 20. Upper Eocene, Alabama.
———*sp. A* Cushman and Todd, *67*, p. 57, pl. 10, fig. 11. Paleocene, Arkansas.
*Polymorphinella sp.* Cushman, *56*, p. 20, pl. 4, fig. 21. Upper Eocene, Alabama.
*Polyphragma sp.* Cushman, *58*, p. 51, pl. 15, figs. 15, 16. Upper Cretaceous, Texas.
*Pseudofrondicularia sp. A* Detling, *81*, p. 355, pl. 49, figs. 6, 7. Eocene-Oligocene, Oregon.
*Pseudoglandulina sp.* Cushman, *58*, p. 77, pl. 27, fig. 36. Upper Cretaceous, Trinidad.
*Pseudopolymorphina sp. A* Cushman and Todd, *67*, p. 57, pl. 10, fig. 8. Paleocene, Arkansas.
——— *? sp.* Detling, *81*, p. 354, pl. 49, figs. 11, 12, 14. Eocene, Oregon.
*Pseudoschwagerina ? sp.* Thompson and Hazzard, *221*, p. 49, pl. 16, figs. 1–5. Permian, California.
*Pullenia sp.* Germeraad, *102*, p. 72, pl. 5, figs. 3, 4. Pliocene, Ceram.
*Quinqueloculina sp.* Cushman, *58*, p. 48, pl. 16, figs. 12, 13. Upper Cretaceous, Texas. For: *Quinqueloculina rotunda* Carsey, 1926, (*non* Roemer, 1838), Texas Univ. Publ. 2612, p. 50, pl. 1, fig. 3.
———*sp.* Detling, *81*, p. 352, pl. 46, fig. 5. Eocene, Oregon.
*Rectobolivina sp.* Germeraad, *101*, p. 68, pl. 3, figs. 17, 18. Pliocene, Ceram.
*Reophax sp.* Cushman, *58*, p. 17, pl. 1, fig. 26. Upper Cretaceous, Trinidad.
*Robulus sp.* Cushman, *56*, p. 10, pl. 2, fig. 11. Upper Eocene, Alabama.
———*sp.* Cushman, *58*, p. 55, pl. 18, fig. 11. Upper Cretaceous, Tennessee.

———*sp.* Cushman and Todd, *67*, p. 48, pl. 7, figs. 15, 16. Paleocene, Arkansas.
———*sp. A* Cushman and Gray, *64*, p. 12, pl. 2, fig. 15. Pliocene, California.
———*sp. B* Cushman and Gray, *64*, p. 12, pl. 2, fig. 13. Pliocene, California.
*Schwagerina sp.* Thompson and Wheeler, *221*, p. 27, pl. 1, fig. 5. Permian, California.
———*sp. A* Dunbar and Newell, *83*, p. 469, pl. 3, fig. 11. Permian, Bolivia.
*? Siphonodosaria sp.* Germeraad, *102*, p. 69, pl. 3, fig. 20. Pliocene, Ceram.
*Spiroloculina sp.* Cushman, *58*, p. 49, pl. 14, figs. 24, 25. Upper Cretaceous, Texas.
———*sp.* Cushman, *56*, p. 6, pl. 1, fig. 12. Upper Eocene, Alabama.
*Spiroplectammina sp.* Loeblich, *130*, p. 136, pl. 22, fig. 9. Upper Cretaceous, Texas.
*Textularia sp.* Cushman and Renz, *65*, p. 20, pl. 2, fig. 14. Upper Cretaceous, Trinidad.
*Trochammina sp.* Cushman, *58*, p. 51, pl. 15, fig. 14. Upper Cretaceous, Texas.
——— *? sp.* Detling, *81*, p. 353, pl. 47, figs. 1–3. Eocene, Oregon.
*Trocholina sp.* Mohler, 149, (published July 31, 1947), p. 301, text fig. 1. Lower Cretaceous, West Borneo.
*Uvigerina sp.* Cushman and Gray, *64*, p. 37, pl. 6, fig. 15. Pliocene, California.
———*sp.* Detling, *81*, p. 358, pl. 50, fig. 9. Eocene-Oligocene, Oregon.
*? Uvigerina sp.* Germeraad, *102*, p. 43, pl. 5, figs. 32–34. Upper Cretaceous, Ceram.
*Vaginulina sp.* Cushman, *56*, p. 14, pl. 4, fig. 1. Upper Eocene, Alabama.
———*sp. A* Cushman and Todd, *67*, p. 55, pl. 8, fig. 11. Paleocene, Arkansas.

## NOMINA NUDA

In the foraminiferal literature for the year 1946 the following *nomina nuda* were noted:

From the Carboniferous of Poland, Aisenverg, Brazhnikova, Novik and Shoulga, *5*, cite on p. 52 the following Foraminifera (apparently new), which are here regarded, for the time being, as nomina nuda, until complete references are available:

*Forschia* with *Forschia subangulata* (Moll.) as (?) genotype;
*Haplophragmella irregularis* Raus.
——— *tetraloculi* Raus.
*Lituotubella*, apparently a new genus
——— *glomospiroides* var. *magna* Raus.
*Monotaxis*, apparently a new genus
——— *gibba* (Moell.)
*Parastaffela*, also a new genus
——— *struvei* (Moell.).

Samoilova, *176*, lists on pp. 52/53 of the Russian text, the following apparently new forms from the upper Paleocene of the Crimea:

*Bulimina schichkinskii* Samoilova
*Cibicides dutemplei* (d'Orb.) var. *oligocenicus* Samoilova
——— *pseudoperlucidus* Bykowa
——— *pygmaeus* (Hantken) var. *almaensis* Samoilova
*Ellipsonodosaria helenae* Samoilova
——— *volgensis* Samoilova
*Pulvinulinella almaensis* Samoilova
*Valvulineria iphigenia* Samoilova

Semichatova, *180*, cites the following new genera and species from the Upper Carboniferous of U.S.S.R.:

*Fusulinella mira* S. V. Semikhatova (p. 529)
*Prototriticites* gen. nov. F. S. Putrya (p. 530)
*Rugofusulina schwageriniformis* Semikhatova (p. 531)
——— *rauseri* Semikhatova
*Triticites donensis* Semikhatova
——— *priscoidea* Semikhatova

Kikoine, *121*, published from the Upper Cretaceous of the Pyrenees, France *Globotruncana spinea*, with short description but without figures. This new species was, however, validated by Kikoine in: Comptes-rendus, Soc. géol. France, 1947, pp. 19–22.

Rosovskaya, *173*, p. 558 mentions *Pseudotriticites* Putrja, 1930, and also *Prototriticites* Putrja, 1940, (see Semichatova, *180*, *ut supra*) but does not indicate the respective genotypes of Putrja's new genera. The compiler is unaware whether Putrja, whose 1940 paper is not available, has designated genotypes and/or erected new species. The two new genera are, for the present, regarded as *nomina nuda* until the publication is available.

Ruiz de Gaona, *174*, mentions the following new forms: *Nummulites batalleri* on p. 198, with no description and no figures; *Nummulites gomezi*, p. 199, with short description but no figures; *Nummulites colomi*, on p. 204, with short description, but no figures; *Discocyclina roberti* H. Douvillé, var. *vasconica*, on p. 204, not described, but illustrated on pl. 2, fig. 26; and *Discocyclina roberti* H. Douvillé, var. *llarenai*, on p. 204, not described, but figured on pl. 2, fig. 28.

## SUPPLEMENT TO INDEX FOR 1938

Ciry, *251*, whose paper was not available to the compiler, describes in this publication at least one new species, *Staffella haymanaensis* n. sp. from the Permian of Turkey.

## SUPPLEMENT TO INDEX FOR 1940

In the paper by F. and G. Kahler on the fusulinids of the lower-most Permian of Tienshan, listed in my "Bibliography of Foraminifera for the year 1940" (Jour. Paleontology, vol. 17, July 1943, p. 392, No. 89), at least two species are new: *Pseudoschwagerina aequalis* n. sp., and *Pseudoschwagerina nitida* n. sp. The paper was not available to the compiler.

## SUPPLEMENT TO INDEX FOR 1941

F. and G. Kahler's publication, *277*, not available to the compiler, contains besides 4 new species the following new names: *Pseudoschwagerina cheni* and *Pseudoschwagerina leei*.

## SUPPLEMENT TO INDEX FOR 1943

*Crateriola* gen. nov. (nom. nov.) Strand, 1943, Folia Zool. et Hydrobiol., vol. 12, No. 1, p. 211. New name for: *Craterella* Dons, 1942, Kong. Norske Vidensk. Selskab Forhandl., vol. 14,

Nr. 36, p. 136, which is preoccupied by *Craterella* Schrammen, 1901, Monatsb. Mus. Hildesheim, Nr. 14, p. 4 (Lithistidae).

*Pseudogaudryina ?apenninica* Montanaro-Gallitelli, Atti Soc. Toscana Sci. Nat., Mem., vol. 52, p. 13, pl. 2, figs. 1–3. Upper Cretaceous, Appenines, Italy.

*Trochamminoides glomospiroides* Montanaro-Gallitelli, *ibid.*, Mem., vol. 53, p. 11. Onomatype. Upper Cretaceous, Apennines, Italy.

## SUPPLEMENT TO INDEX FOR 1944

*Paraschwagerina sera* Erk, Metea, Maden Tetk. ve Arama Enstitüt. Yayinland, Ankara, series B, No. 9, p. 254, pl. 22, figs. 1–3. Permian, Turkey.

*Polydiexodina bithynica* Erk, *ibid.*, series B, No. 9, p. 264, pl. 23, figs. 1–8; pl. 24, fig. 1. Permian, Turkey.

——— *diskayensis* Erk, *ibid.*, series B, No. 9, p. 260, pl. 22, figs. 4, 5; pl. 24, figs. 4–6. Permian, Turkey.

*Schwagerina navillei* Erk, *ibid.*, series B. No. 9, p. 251, pl. 21, figs. 3–5. Permian, Turkey.

*Torresina* gen. nov. Parr, Jour. Roy. Micro. Soc. London, (3), vol. 64, p. 130. (Published 1947). Family: Rotaliidae. Genotype: *Torresina haddoni* Parr, 1944, *ut infra*. Recent, off Eastern Australia; Pliocene. [*Cave: Torresia* Castelnau, 1875, (fish), and *Torresia* Brongersma, 1936 (Reptil.)].

——— *haddoni* Parr, *ibid.*, (3), vol. 64, (published 1947), p. 133, pl. i, figs. 4–6; text fig. 3. Recent, off eastern Australia, Torres Strait, Raine Island, 155 fathoms.

——— *intermedia* Parr, *ibid.*, (3), vol. 64, (published 1947), p. 130, pl. 1, fig. 1; text fig. 1. Recent, off Raine Island, Torres Strait, Australia, 155 fathoms.

*Yangchienia elongata* Erk, Metea, Maden Tetk. ve Arama Enstitut. Yayinlarindan, Ankara, series B, No. 9, p. 243, pl. 20, figs. 3, 4. Reworked, Permian boulder, in conglomerate at base of Malm, Turkey.

## SUPPLEMENT TO INDEX FOR 1945

*Silicotextulina melchersi* Frenguelli, Museo de La Plata, Notas, vol. 10. (publication not seen by compiler). Recent, Argentina. (Note: The only figure seen of this species, is in: Frenguelli, 1946, Museo de La Plata, Notas, vol. 11, Zool No. 96, p. 345, text fig. 1. Recent, Argentina).

## SUPPLEMENT TO NOMENCLATURA APERTA 1943 AND 1944

1943: *Miogypsina sp.* Hanzawa, Geol. Soc. Japan, Jour., vol. 50, No. 595, p. 249, pl. 9, fig. 3. Lower Miocene, Sagara oilfield, Japan.

1944: *Alveolina* n. sp. Erk, Metea, Maden Tetk. ve Arama Enstitu. Yayillarindan, Ankara-Istanbul, series B, No. 9, not described, pl. 18, fig. 2-2. Eocene, Turkey.

——— n. sp. Erk. *ibid.*, series B. No. 9, not described. Pl. 18, figs. 2-4 to 6. Eocene, Turkey.

*Doliolina* n. sp. Erk, *ibid.*, series B. No. 9, p. 271, pl. 25, fig. 2. Permian, Turkey.

## SUPPLEMENT TO NOMINA NUDA 1941

*Astrorhiza cretacea* Taubert, 1941, N. Jahrb. f. Min. etc., Beil.-Bd. 86, Abt. B, table opposite p. 140. Upper Cretaceous, Germany.

JOURNAL OF PALEONTOLOGY, VOL. 22, NO. 2, PP. 222–224, 5 TEXT FIGS., MARCH 1948

# *MANORELLA*, A NEW GENUS OF FORAMINIFERA FROM THE AUSTIN CHALK OF TEXAS*

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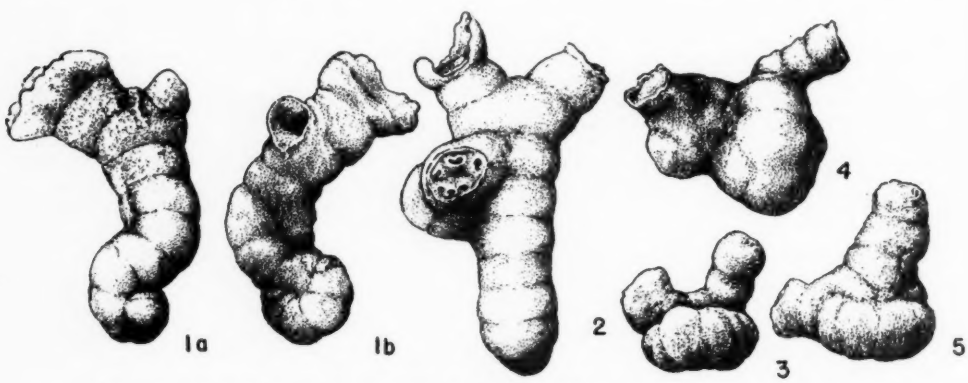
ABSTRACT—A new genus and species of Foraminifera, *Manorella proteus* is described, and revision of the family Placopsilinidae is suggested.

STUDY of a sample of Austin chalk from near the city of Austin, Texas, yielded a suite of more than 50 specimens of an extremely variable foraminifer which could not be placed in any known genus or species. These are described as *Manorella proteus*, new genus and species. They do not accord with any published description of a family or subfamily available and suggest that a revision of Cushman's (1940) family Placopsilinidae is to be desired.

Examination of specimens prior to description included decalcification with dilute hydrochloric acid and the preparation of thin sections, in addition to the conventional study of exteriors.

The holotype and figured paratypes of the species will be deposited in the Cushman Laboratory of Foraminiferal Research, Sharon, Massachusetts. Other paratypes will be placed at the University of Texas and other institutions in the United States.

*Acknowledgements:* I am indebted to Dr. Don L. Frizzell, of the Department of Geology, University of Texas, for his aid and guidance in the preparation of this note, and to Mrs. Sarah B. Martin, of the Department of Zoology and Physiology, University of Texas, for the accompanying drawings.




FIGS. *1a, b, 3–5*. Paratypes, × 30, showing variability in coiling and branches.
FIG. *2*. Holotype, × 30, showing apertures.

*Locality description:* Bureau of Economic Geology station 226-T-4: "Top of Austin chalk close to bridge over Little Walnut Creek on Austin-Manor highway, 3.9 miles by road from the corner of East Avenue and 22nd Street in Austin (Travis County, Texas), . . . A soft yellowish layer in the top of the exposure . . . This is the type locality for *Vaginulina regina* Plummer [="V". *texana* Cushman]" (Plummer, 1931, p. 120); collected by Don L. Frizzell, January 1, 1946.

The sample containing *Manorella proteus* n. sp. was taken about eight feet strati-

* A contribution from the Department of Geology, the University of Texas, Austin, Texas.

graphically below the contact with the overlying Taylor clays. It included both the yellowish stratum and the adjacent bluish chalk, each lithologic element furnishing specimens. The material is extremely fossiliferous.

SYSTEMATIC DESCRIPTION

Order FORAMINIFERA

Family PLACOPSILINIDAE?

Subfamily POLYPHRAGMINAE

Genus MANORELLA Grice, n. gen.

*Genotype: Manorella proteus* Grice, n. sp.

*Description.*—Test calcareous, coarsely perforate, with a chitinous lining, consisting of an initial trochoid coil followed by a bifurcating uncoiled portion, plane of coiling 90 degrees from axis of uncoiled part, branching from coiled or later part or both; aperture multiple, consisting of slits produced on collar-like projections, usually parallel to the periphery rarely with additional central apertures.

*Discussion.*—*Manorella* is similar to *Polyphragma* Reuss (1871, p. 277; Cushman 1940, p. 192, key, pl. 19, figs. 8–10) in that the test branches, and the uncoiled portion is cylindrical. Both forms have tests that are at least in part calcareous and perforate. *Polyphragma*, however, is described as having an external arenaceous layer that is lacking in *Manorella*. They differ also in that *Manorella* has a definitely non-labyrinthic interior and does not have a simple cribrate aperture. These similarities and differences are believed to show that *Manorella* may be referred to the same subfamily as *Polyphragma*. It is more primitive in structure and probably more closely related to the ancestral stock of both genera. This relationship is inferred from the fact that in Galloway's (1933) postulated evolution of the wall structure, calcareous perforate forms are held to be more primitive than arenaceous forms. Further indication of this may be found in Cushman's (1940) conclusion that labyrinthic chambers usually show the approaching culmination of a group. The apertures of *Manorella* show a more advanced stage of development than those of *Polyphragma* in that they are produced on collar-like projections.

A thin section of *M. proteus* showed a jagged layer of material, apparently crystalline calcite, on the internal wall of the test inside the chitinous lining. It is very likely that the supposed labyrinthic interior described for *Polyphragma* is a similar layer of crystalline calcite rather than true labyrinthic structure. If so, the strongest objection to assigning the two genera to the same family would be removed. Very little seems to be known about *Polyphragma*. Galloway (1933), for example, considered that it might even be a bryzoan. The figures available are copies of the original, except for illustrations of a Texas form which may not be typical (see discussion of *M. proteus*).

MANORELLA PROTEUS Grice, n. sp.

*Description.*—Test calcareous, coarsely perforate, with an internal layer of thin, clear, chitinous material; test of medium size, extremely variable in form, consisting of an initial coil, apparently trochoid and shown in thin section to consist of at least two whorls, followed by a branching uncoiled portion, bifurcating at 90 degrees from either coiled or uncoiled portion or from both; plane of coiling 90 degrees from axis of uncoiled part; four to six chambers in initial coil, two or more in uncoiled portion, slightly inflated, forming alternating wedges, moderately overlapping, maximum height of chamber of about $\frac{2}{3}$ of width, last two chambers sometimes change direction of growth; branching may be directly from coiled portion or from uncoiled portion, may be recumbent on coiled or uncoiled portion, sometimes with branches reaching a maximum of four in suite studied; sutures straight, slightly incised, distinct in uncoiled portion, somewhat obscured in coil; apertures three to eleven (commonly about four or five) consisting of slits on collar-like projections, parallel to periphery of chamber, mostly peripheral but rarely with additional central apertures.

*Discussion.*—Specimens of an unnamed species referred to *Polyphragma* (Cushman, 1946, p. 51, pl. 36, figs. 15a–b) are associated with *Manorella proteus*, but are very distinct in their morphological characters. They are coarsely arenaceous, at least externally, and differ in characters of the aperture. Moreover, they do not branch. Since the initial chambers are unknown, the degree of pos-

*Dimensions of figured specimens:*

| | Length (mm.) | Max. Diameter Uncoiled Portion (mm.) | Max. Diameter Initial Coil (mm.) |
|---|---|---|---|
| Holotype fig. *2* | 1.48 | 0.48 | 0.36 |
| Paratype fig. *1a, b* | 1.23 | 0.33 | 0.38 |
| Paratype fig. *3* | 0.59 | 0.25 | 0.40 |
| Paratype fig. *4* | 0.84 | 0.26 | 0.48 |
| Paratype fig. *5* | 0.77 | 0.29 | 0.42 |

sible relationship with *Manorella* cannot be determined.

*Manorella proteus* has been found only at the type locality. Possibly it is a facies-controlled form, or it may be restricted to depositional pockets. The species is extremely variable. In the study of over fifty specimens, no two were found to be alike in shape. No closely related forms have been found in the literature available.

The trivial name is a noun in apposition.

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GALLOWAY, J. J., 1933, A manual of Foraminifera Bloomington, Indiana, pp. 1–483, pls. 1–42.

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JOURNAL OF PALEONTOLOGY, VOL. 22, NO. 2, PP. 225–232, 2 TEXT FIGS., MARCH 1948

# INFRASPECIFIC CATEGORIES IN INVERTEBRATE PALEONTOLOGY*

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EVOLUTION as a modern philosophy requires the synthesis of paleontology, genetics, and neontology. Although fossils supply a truly enormous number of documentary records of evolution through vast spans of time, paleontology cannot explain the mechanics of evolution. It is equally certain that genetics and neontology cannot formulate a satisfactory explanation of evolutionary phenomena without the data which paleontology alone can supply. If paleontological evidence is effectively to be brought to bear on problems of evolution, it is necessary that paleontologists, geneticists, and neontologists understand each other. They must be familiar with the methods and problems of common interest in each of the disciplines which bear on evolution.

One impediment to a fuller evaluation of the fossil record is the all but universal practice of basing "species" and "varieties" on single specimens, or at most, a few specimens, which become the fixed standards for identification of new material. This is the method subscribed to by the early taxonomists who believed that species were individually created, and hence are disparate entities. Adequate samples commonly are not available in paleontology. In many cases, however, the material available for study is adequate but is not utilized to the fullest extent. This procedure does not permit consideration of the inherent variability of organisms, and leads to an artifact wherein spurious discontinuities are placed within completely gradational contemporaneous series.

Failure to take into consideration the variability of organisms in taxonomy is tantamount to the rejection of one of their most important attributes. Wood and Barnard (1946, p. 94) have cited an illustration of the absurd lengths to which paleontologists may go to limit their taxonomic categories within arbitrary boundaries. Relative to the high variability of certain Foraminifera Heron-Allen once approvingly quoted an admonition by F. W. Millet, "In preparing your slides you should be very careful to select typical specimens only, the intermediate things are a nuisance and should be severely ignored, unless the types are absent from the deposit. . . . Take *Globigerina*, the difference between *G. cretacea* and *G. linnaeana* is very great, but you can select specimens which will form a complete chain from one to the other" (Heron-Allen, 1894).

This taxonomic philosophy generally is being supplanted in neontology by emphasis on population studies. Collections of specimens are now thought of as samples of populations. Such samples provide a valid measure of population variability when properly analyzed by quantitative methods.

*The lower taxonomic categories.* Several taxonomic categories below the species have been employed in zoology. Of these, the subspecies and variety have been most used in the past. The variety, however, rarely is employed now by progressive taxonomists, many of whom object to its use on grounds to be indicated below. On the lower taxonomic levels modern systematics is concerned with the study of populations[1]—subspecies and species. The variety, as most generally

* Reprinted from Evolution, vol. 1, pp. 163–171, 1947. This subject is of such importance that it should be brought to the attention of all paleontologists.—Ed.

[1] As generally understood an animal population includes all closely allied actively interbreeding individuals. Implicit in this concept is the idea of contemporaneity. We may speak of past or future populations, or of successive populations. Thus a population does not have time duration. A subspecies certainly does have time duration; hence a subspecies is composed of a succession of gradually changing populations.

understood in neontology, is based on individuals within populations, hence is an artificial category. In paleontological literature, on the other hand, the term subspecies rarely is encountered, but the variety is widely used.

In later years many students of invertebrate fossils have made use of the variety category for whole populations.[2] This is a special and ambiguous use of the term which is certain to be misunderstood.

Subspecies in neontology are entire populations, or races, which have become differentiated through some degree of isolation over a shorter or longer period of time (Mayr, 1942). Since subspecies do interbreed freely when brought together, under *natural* as well as artificial conditions, they cannot become differentiated, or maintain their identity except through continued partial or complete isolation. Hence, closely related subspecies are not found living together in the same geographic and ecologic sites, nor are they likely to occur together in a single fossil faunule.

The emphasis on population studies of animals in the fields of systematic zoology and genetics if focusing attention on the special significance of the subspecies in animal evolution. It is the actively interbreeding population which changes as a unit in response to genetic changes and to selection pressure. Subspecies generally are not so distinctive morphologically as are species; hence, careful analysis of adequate samples may be necessary for their differentiation. Unfortunately, modern biometrical methods have not yet been generally adopted in paleontology. Consequently we know very little about fossil subspecies.

The variety, as understood in neontology, and as commonly employed in paleontology, is applied to distinctive morphological types, kinds, or variants—individuals or groups of individuals within a population. Such variants do not in themselves constitute natural populations, but are only artificially extracted constituents of a population. Thus they are not simply smaller categories of the same sort as a subspecies, but are a different kind of category. A subspecies may be analyzed as made up of varieties. Since, however, the varieties are not populations they do not stand in the same relation to subspecies as subspecies do to species. A variety is not a smaller and more homogeneous sort of subspecies.

*The variety in paleontology.* Because of traditional preoccupation with the useful applications of paleontology in stratigraphic work many paleontologists have felt that their material calls for special treatment, whereby distinctive specimens, or groups of specimens, are given formal varietal names.[3] In most cases such distinctive material intergrades with slightly different forms in the same lot. Complete intergradation may not be evident if the collection is very small, or has been carelessly analyzed. The great mass of documentary data on animal variation demonstrates that graded morphological series are the rule in any population. Although so obvious as commonly to be overlooked, the probabilities are very great that similar individuals found in association are indeed members of a single population. Slight morphological disparity is hardly as weighty as the circumstance of mutual association in the rocks. According to traditional practice, still followed by the majority of invertebrate paleontologists, morphological groups are selected from the intergrading series of a single lot, and each group deviating in one way or another from the "typical" form is given a varietal name. This is the "type" method where a single specimen (holotype) may be selected as a standard for the "definition" of a species. This method is described well by Trueman

[2] Like a number of other workers I have intended to apply the variety category to natural populations in my own work (e.g., Newell, 1937 and 1942). Such population "varieties" are not of the same sort as are the varieties of neontology. The former are in fact subspecies and species.

[3] Failure to regard the lower taxonomic categories as populations rather than as specimens has led some students of invertebrate fossils into orgies of species- and variety-naming. For example, Reed has recently described 129 new species and 131 new varieties of Permian brachiopods from a rather well-known fauna (Reed, 1944). It seems that the great majority of these "new" forms were based on individuals, and are not representative of populations. See also Fucini, A., "Fossili Domeriani dei Dintorni di Taormina," Pal. Ital., vols. 26, 27, 29–31, 35, 1920–35.

and Weir (1946, p. xx): "We continue to follow the practice . . . of limiting the specific name to forms which are practically identical with the holotype of the species. Thus we regard the holotype as forming a fixed point in the evolving plexus which we take to represent the lineage. . . . We may accept the species as forming something more than a point in the plexus, a narrow ring around the holotype including forms which may be accepted as falling within the species." Probably the greatest shortcoming of this method lies in fact that it does not provide a valid measure of the population from which the material is taken. The dimensions of the "narrow ring around the holotype" are not only necessarily arbitrary, but the limits of variability indicated for a given form must be far more restricted than those of the natural population. Furthermore, holotypes commonly are not the biologically most typical representatives of a species, and arbitrarily to draw a circle (or a spheroid) about them cannot limit a natural species. Arbitrary definitions of species like this correspond in a way to varieties in that they represent morphological groups arbitrarily extracted from much more variable populations.

Trueman and Weir, in their important work on highly variable non-marine bivalves, do not advocate the use of varietal names. They favor careful analysis of population samples by quantitative methods. They make an interesting suggestion for a solution of the often vexing problem of treatment of "nontypical" material. "In communities there will be other forms differing more widely from the holotype, and we have tried to indicate in suitable cases the extent of variation which we shall allow for forms recorded with the prefix 'aff.' . . . For other forms not known to be related to the holotype, though possibly showing greater similarity in some features, the use of the prefix 'cf.' is recommended" (Trueman and Weir, 1946, pp. xx, xxl). This interesting procedure provides a logical and conservative method for the classification of very small samples. However, it does not allow for the recognition of infraspecific populations where the samples are adequate.

Paleontologists sometimes justify the naming of artificial groups within populations on the grounds that some varieties are particularly striking, hence easily recognized. They may appear to be confined to certain stratigraphic levels. Narrow stratigraphic range, although readily demonstrable for a given locality, probably is not characteristic of the absolute time ranges for most varieties.

Swinnerton (1940) has called attention to the excessive splitting of the genus *Beaniceras*, a Jurassic ammonite, in which seven species and seven varieties have been erected in what is regarded as one interbreeding population. Wood and Barnard, in a particularly significant quantitative study of some Jurassic Foraminifera, have suggested that ***if names are needed*** for intrapopulation variants, or clines, recourse to trinomial or quadrinomial nomenclature seems called for (Wood and Barnard, 1946). These lesser taxonomic units admittedly do not correspond to populations.

It is overlooked or ignored by many that intra-population groups, no matter how valid may be their morphological distinction (as, for instance, with sexual dimorphism), do not play the same role in evolution as populations. In those cases where successive populations can be distinguished by different proportions of varieties stages in evolution can be defined by the differing proportions. These will, of course, give each successive population its own distinctive average or modal characters as a whole. In such cases there is no evident advantage in applying names to the varieties instead of the whole population.

The application of formal scientific names to conspicuous variants within a population tends to obscure relationships and hence is undesirable. This practice has been likened to the formal naming of red-haired, black-haired, and blond-haired people; or those characterized by harelip-clubfoot, dwarfing, etc. (Mayr, 1942, p. 104). Equally untenable would be the naming of males and females of mammals, or the polymorphic forms of protozoans.

It is apparent that the recognition of varieties is highly useful for the ready identification of strata, within limited areas. It is equally certain that varieties serve no

useful function in studies of phylogeny. The stratigraphic aim can be attained by labeling varieties with symbols or letters, thereby avoiding confusion with the basic population categories, the subspecies and species. Artificial groups should not be given formal names under Linnaean nomenclature.

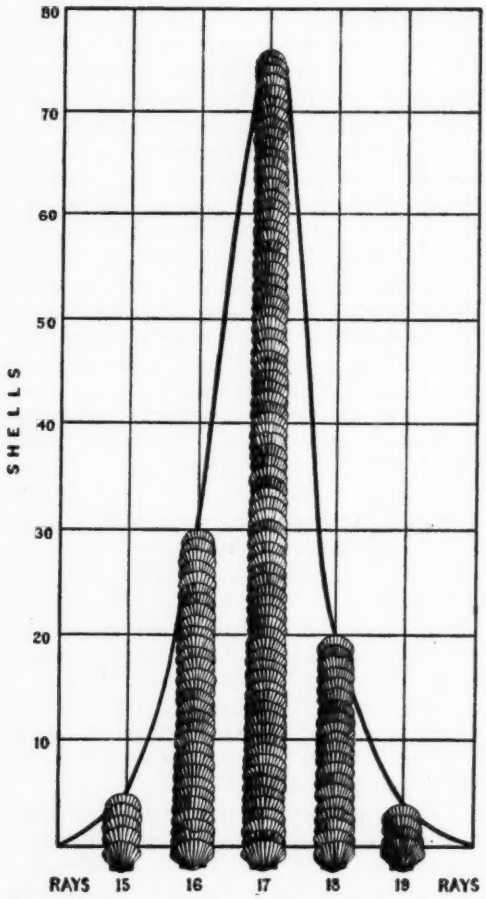


FIG. 1—The normal curve of variation as shown by a pailful of scallops collected on an Atlantic beach. The morphological classes are of the sort commonly described as varieties by some invertebrate paleontologists (Am. Museum Natural History).

It is a well-known fact that molluscs, coelenterates, and other groups of invertebrates develop differently in varying habitats. Fluctuations in temperature, salinity, food supply, and currents result in the development of characteristic forms, ecophenotypes, in which the genetic complex is not different from that of the "normal" forms. These are not comparable with ecologic races, in which a population becomes adapted by genetic changes to a specific ecologic niche. Probably it may never be possible to distinguish between ecophenotypes and ecologic races in paleontology. In the former category the characteristic morphology does not typify an entire population, in the latter it does. The two should be given different taxonomic treatment wherever possible. In neontology, the ecophenotype would be considered a variety, the ecologic race would be a subspecies, if sufficiently distinct.

Ecophenotypes very commonly characterize an entire faunule, or all of the individuals of a community, e.g., the dwarf molluscs of brackish waters. Paleontologists probably will agree that variants of this type, because of their abundance, and their importance as indicators of environment, are deserving of formal names. They do not characterize whole populations, but they are characteristic of communities, within the population. It will be convenient to treat them as though they were subspecies, lacking evidence to the contrary.

Aside from the biological problems involved in subspecies and varieties there is a purely legalistic problem to be considered. The only infraspecific category expressly provided for by the International Rules of Zoological Nomenclature is the "subspecies"; hence, the legality of all names proposed as varieties is surely debatable. It appears to many taxonomists that the only way out of this dilemma is for the Commission to clarify "subspecies" as given in Article XI of the Rules, at the same time expressly excluding from formal nomenclature all infraspecific categories which are not believed to apply to whole populations. Such ruling would not, of course, be retroactive.[4] It is argued by some that the Commission should not be concerned with the definition of taxonomic categories like "variety," "subspecies," etc. It seems to me, however, that the erection of a complex legal code for the naming of zoological

[4] After completion of the manuscript for this paper I find that Hatch (1946) has arrived at the same conclusion.

taxonomic units is inadequate without provision for some general agreement as to the nature of these units. Without attempting to define precisely the species and subspecies the Rules could well be amended to state that infrageneric taxonomic units are by intention natural populations.

*Population categories in invertebrate paleontology.* Classification of fossil animals presents certain difficulties not met in the taxonomy of living forms. Paleontology is concerned not only with single floras and faunas, nor even with fossil biota from contemporaneous, geographically separated deposits. A collection of closely allied forms may represent a large number of successive time horizons and geographically separate localities. Furthermore, progressive modifications may be due to evolution, or to ecophenotypic variation produced by gradually shifting environments. Species of living animals are discontinuous, contemporary entities. They have real limits, but subspecies intergrade marginally. Paleontologic materials include temporal sequences which are more or less completely gradational, the familiar "evolutionary series." Such series rarely are uninterrupted, because the fossil record in any locality is not complete for any considerable span of time, and because animal communities shift laterally with environmental changes. In all probability, evolution invariably has been accompanied by gradual morphological change, hence "in a phylogenetic continuum a 'species' (in contradistinction to the limiting concept) is a kind of nebulous and fluctuating area in a ceaseless process, and has no temporal, morphologic, or genetic boundaries between it and preceding or subsequent areas" (Jepsen, 1943, p. 528). This applies as well to infraspecific populations. Explosive evolution, during which rates of evolution are greatly accelerated, does not imply discontinuities in the evolutionary process, although gaps in the fossil record are likely to be most evident where evolution has been most rapid. The theory that new species of animals may be created by single large mutations has little support among geneticists. These gaps conveniently delimit vertical species and morphologic grades of less than specific rank in a phyletic line.

Relatively continuous vertical series, separated from related series by gaps, are common in paleontology, Brinckmann's classical study of certain Jurassic ammonites (1929) illustrates particularly well uniform and continuous evolution through limited stratigraphic sequences, interrupted here and there by gaps, probably due to depositional hiatus. Similar examples are known in most of the more studied groups of fossil invertebrates, e.g., Foraminifera (Dunbar and Henbest, 1942), Mollusca (Neumayr and Paul, 1875; Gorjanovic-Kramberger, 1901; Burnett-Smith, 1906; Woods, 1912; Kitchen, 1912; Lang, 1919; Trueman, 1922; Newell, 1937, 1942), Brachiopoda (Kiaer, 1908; Jones, 1928; Teichert, 1930; Fenton, 1931), Bryozoa (Lang, 1917, 1921), Echinoderma (Rowe, 1899; Spencer, 1913), Anthozoa (Carruthers, 1910; Lang, 1923, 1938), Graptoloidea (Elles, 1922; Bulman, 1933).

These evolutionary series hardly ever are absolutely continuous through appreciable stratigraphic intervals, in the sense of broadly overlapping modal peaks. Adequate quantitative analysis will certainly reveal at least small discontinuities between the fossil records of successive populations, even where there are marginal overlaps of the variability curves. In practice the division of vertical series into species often can, and in that case should, correspond to gaps in the record. As further collecting tends to eliminate or reduce the gaps, newly discovered material may have to be arbitrarily referred to one or the other of closely related populations, so that ultimately the limits between two species might be quite arbitrary. This is an inevitable consequence of evolution.

Modern taxonomic practice in zoology limits subspecies to geographical and ecological races, populations which have achieved limited genetic differentiation through isolation. Subspecies of living animals, of course, are contemporaneous, and it commonly is implied that the main factor in their development is isolation. Isolation is the factor which prevents hybridization and consequent swamping of gene complexes, i.e., it is the factor which enables subspecies to maintain their special characteristics. Although the isolating fac-

tor is crucial in subspeciation, time is equally important in the development of subspecies, and has been neglected in most discussions, perhaps because its role is so obvious. Natural selection, operating on gene complexes is effective in proportion to the time through which it acts, other factors being equal. Thus, time is needed for the development of morphologically and geneticaly distinct separated fossil races seldom, perhaps never, can be positively established. The majority of fossil species are known to have appreciable time duration, amounting in some cases to an entire geological period (20 to 40 million years). It appears quite logical and practicable to distinguish geographic races, subspecies, within the time range of these species. Correlation of the enclosing strata

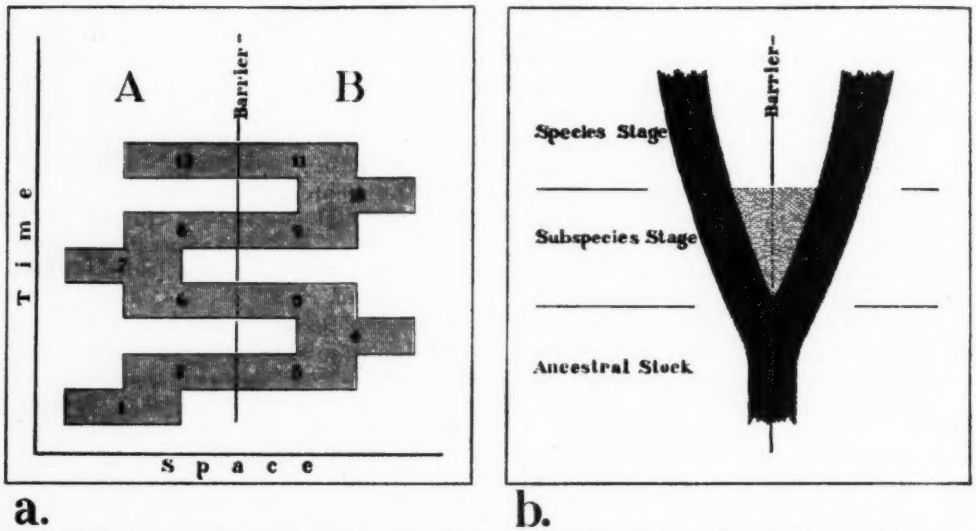


FIG. 2. (a) Diagram illustrating how geographic fragmentation of successive populations (the numbered rectangles) may accompany vertical differentiation of a phyletic line. The populations rarely remain in one locality for long, but migrate. Some migrants become isolated from the parent stock by barriers, becoming ultimately differentiated into geographic races. The faunal succession in any locality (A or B) is never absolutely continuous, even though gaps may be obscure. Those gaps may be produced by migrations, by depositional hiatus, and by local extermination.
(b) A population becomes divided by a barrier causing partial isolation with limited gene flow for a time—the subspecies stage in speciation. After sufficient genetic differentiation has been reached interbreeding ceases, gene flow is stopped, and the two branches become separate species.

races. Isolation over an insufficient time cannot result in the development of a new subspecies or species. Whether or not the temporal requirement is great or small for a given subspecies is beside the point. The time factor certainly is as significant as isolation.

Subspecies in neontology are geographical (and ecological) races, and many paleontologists conversant with this subspecies concept hesitate to employ subspecies in paleontology because of the great difficulty in establishing exact synchroneity of geographically separate fossil populations. As a matter of fact exact contemporaneity of can usually satisfactorily be established with an accuracy which falls well within the total limits of the vertical range of a species.

It is highly improbable that a phyletic series ever evolves continuously at one locality over a considerable span of time. Successive populations migrate back and forth across the place of origin of the parent stock. During the history of any animal lineage geographic isolation certainly has played just the same role at successive time horizons which it now plays. The conclusion is unavoidable that geographical segregation has been a factor in the development of the morphological grades found at successive

stratigraphic levels (figure 2). Horizontal (allopatric) subspecies and vertical (allochronic) subspecies cannot be distinguished from each other in fossil forms. It is debatable whether they are distinguishable in living forms, since the differentiation of populations into geographic races *is vertical evolution*. Probably temporal and spatial differentiation are inseparable in nature, even though it may be convenient to think of them as separate processes.

In paleontology we badly need an infraspecific category[5] to denote minute stages in evolution admittedly of less than specific rank—the small grades of a phyletic "continuum." Waagen proposed the term *mutation* in just this sense, but paleontology has been deprived of this useful term through its general adoption in a different sense by genetics.

There is no well substantiated reason why we may not employ Linnaean nomenclature for the small grades of a continuous vertical series in the same way as for horizontal distributions. Some students of invertebrate fossils regularly employ the "variety" category for whole populations. Others, hesitating to employ the ambiguous term variety, and considering the subspecies as inappropriate for paleontology, have chosen to label all well-defined populations as separate species, thereby adopting a procedure which fails to indicate the relative degrees of morphological similarity between successive populations. This method also fails to indicate the degree of difference normally found between good species of living animals.

## SUMMARY

It may be concluded, then, that the subspecies category may logically be employed in paleontology, much as it is in neontology, for morphologically distinctive populations in which the average difference between closely related populations is less than that which may conveniently distinguish two species.

[5] This need has been discussed by Simpson (1943, pp. 170–177) who favors the discrimination of vertical subspecies. Bruce L. Clark has proposed the term paleo-subspecies for infraspecific fossil populations (Clark, 1945). This term seems unwieldy, and I can see no advantage in its adoption. Caster (1944) and Elias (personal communication) likewise feel that the term subspecies is not appropriate for fossil populations Caster proposed to introduce the term "Waagen" for the small grades in evolutionary series, and Elias would modify this term to "Waagenon." Advantage in the use of one or the other of these terms over "subspecies" is not at all clear. They are not likely to be generally adopted.

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JOURNAL OF PALEONTOLOGY, VOL. 22, NO. 2, PP. 233–263, PLS. 33–35, 14 TEXT FIGS., MARCH 1948

# FOSSIL TINTINNIDS: LORICATED INFUSORIA FO THE ORDER OF THE OLIGOTRICHA

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ABSTRACT—The Upper Jurassic (Tithonian) and Neocomian beds of the Balearic Islands include sediments of very fine structure on a basis of calcite in very small grains, *Nannoconus colomi* (a microorganism *incertae sedis*), Radiolaria, and an enormous quantity of coccolith discs. These sediments are pelagic, with no terrigenous influences. They contain great numbers of loricas of tintinnids (loricated, oligotric infusoria) preserved as calcium carbonate. A few species of fossil tintinnids were already known from other Mediterranean regions under the name of *Calpionella*. The true nature of the Calpionellae was unknown and they were assigned to the Foraminifera by some and to the Radiolaria by others until the author demonstrated that they were tintinnids, and his conclusions were confirmed by Professor Deflandre in 1936. In the present work new forms belonging to different genera and very similar to living forms, are described.

## INTRODUCTION

THE STUDY of the Calpionellae, or fossil tintinnids, from the Tithonian and Lower Cretaceous formations of Spain, is one to which I have devoted several earlier papers. In returning to this subject after an interval of some years I am presenting a résumé of our present knowledge concerning this peculiar and interesting group of planktonic infusoria. This is a subject that the geologist working in the Balearic Islands, and especially in Majorca, will find difficult or impossible to slight, for the fine textured sublithographic limestones of these ages are brought forcibly to his attention both by reason of their wide extent and the importance of the geological facies they represent. The greater part of them is replete with the remains of these organisms and they offer a vast field of study not only to the paleontologist who cultivates this specialty but to the geologist as well, because the data they furnish are important for a detailed understanding of the sediments left by Mesozoic seas in Spain.

In the Tithonian and Lower Cretaceous beds of the Balearics, as well as in strata of the same ages in the eastern part of the Iberian peninsula, myriads of representatives of a plankton characterized chiefly by Radiolaria and tintinnids are preserved. The latter fossils possess the delicate structures of living marine tintinnids and it is remarkable that the extremely fragile and delicate tests or loricas of these Mesozoic species could be so perfectly fossilized.

Since the appearance of my first notes on the Calpionellae in 1934 and 1939, I have continued this study. The following pages present descriptions of new species, both Tithonian and Cretaceous, as well as previously known forms and remarks on the composition and extent of the facies which they characterize. I have also compiled and reviewed all existing data on the Calpionellae, in order to give the most exact idea possible of our present knowledge of them. I have been able to examine in detail various Majorcan deposits containing a very complete pelagic record ranging from the upper Lias to the Aptian-Albian and to follow the tintinnids step by step from their first appearance in the basal beds of the Tithonian to their disappearance in the Barremian.

That the Calpionellae are true fossil tintinnids is no longer doubted by most paleontologists and they are now recognized as such in various authoritative works (Lombard 1945, Murgeanu 1938). This determination is similar in a way to that made in recent years with respect to the Peridiniidae, hystricosferids, etc., which have been found in chert. Such discoveries confirm the words of the famous paleontologist Gaudry who stated, in his work "Fossiles Secondaires" (Vol. II, p. 37, 1890), "Little by little we shall discover in the earth's strata

the ancestors of all the creatures that surround us, however frail they be."

I wish to thank my good friend Dr. Massuti, Director of the Oceanographical Laboratory of Palma (Majorca) and author of numerous works on the western Mediterranean plankton, for constant help in the interpretation of fossil loricas as well as for access to his bibliography on living tintinnids. With his help I have been able to obtain the remains of fossil plankton from the Balearic rocks that were previously unknown. I am also indebted to Professors J. Cadisch and G. Deflandre, of the Universities of Bâle and Paris respectively, both authors of interesting works on the Calpionellae, for information and suggestions and I wish to express my thanks for their assistance.

## SUMMARY OF MORPHOLOGY AND BIOLOGY OF THE LIVING ANIMAL

The tintinnids are oligotric infusoria, generally marine, pelagic and free-swimming, whose protoplasmic mass is lodged in and protected by an organic test or lorica. Some groups live in the ocean (holoplankton) and others inhabit neritic waters (mesoplankton) as, for example, most species of the genus *Tintinnopsis*. Still others exist in fresh water, but at present this is a small group of species. Fossil representatives have been found in Quaternary peat-bogs (Lagerheim 1901).

Plankton samples usually include tintinnid loricas in great numbers, but the body of the animal is nearly always missing. Therefore it is only by laborious investigation on the part of zoologists that an exact knowledge of the complete structure of these infusoria has been obtained.

The first investigator to publish an extensive monograph on this group was Daday (1887), who described the shape of the living animal, the manner in which it is attached to the lorica, the structure of the membranelles, which he considered to be of generic significance, and the number of nuclei in a varied group of species. He also described many new genera and species. Similar investigations were carried on in later years by Laackman (1906) who also studied the nuclear changes which occur during reproduction. Entz, Jr. (1909) published an important work on lorica sections and their histological staining. It was not until Fauré-Fremiet (1924), however, that a detailed work on the vital organization of this group appeared by the French zoologist Fauré-Fremiet who reported new and interesting facts concerning their organization.

The living cell of tintinnids has a bell-shaped or conic form adapted to the size and structure of the lorica. Its lower portion is generally pointed and attached by a narrow, more or less contractile, protoplasmic prolongation, to the bottom or to the side of the lorica. At the opposite end, the thick cylindrical protoplasmic mass is abruptly truncated, forming a disc or peristome varying in width in different species, which is surrounded by a collar bearing on its upper side a wreath of long and narrow ciliary plates, termed *membranelles*. The peristomial disc carries the mouth in a more or less deep pre-oral cavity, into which some of the ciliary plates descend. The latter are delicate and thin, turned outwards and bordered by strong rims. Inwardly, they form a fringe of more or less long ciliated bristles. The peristome is commonly bordered by rounded lobes. In some species there exist at the base of the *membranelles*, on the inner side of the peristomes, peculiar, fine, tentacle-shaped organs—the *tentaculoids*—which seem to be quite variable in length and shape and probably are highly contractile in the living animal. In many species the body bears external fields of cilia, which have been described in detail by Fauré Fremiet. Most marine tintinnids have two large ovoid or rounded macronuclei, each accompanied by a diminutive micronucleus. According to Entz, Jr. the number of nuclei is much greater in certain genera, but this abundance may be related to sporulation which occurs during the reproductive cycle.

The bristles and cilia enable the tintinnids to swim rapidly. Their bodies can extend far out from the lorica and in this position movement is free and easy.

The shapes of tintinnid loricas are very diverse and it is on them alone that the systemmatic arrangement of the group is founded. Little is known about their chemical composition and many investigators of the living plankton have described them as

gelatinous or pseudo-chitinous. The most important morphological features for the determination of living genera and species are characters of the lorica as seen in thin section. Some have prismatic or alveolar structure or a tendency to accumulate various kinds of mineral or organic particles on their surfaces (Fig. 1).

The simplest lorica wall consists of a delicate membrane, apparently structureless, as in *Tintinnus lusus-undae*. A more advanced and complex type is finely reticulated, termed by Brandt "*primary structure.*" In a way this wall is "double" with a single layer of "prismatic elements" between outer and inner laminae. Still more complex loricas possess several layers of "prismatic elements" between the outer laminae.

The loricas of certain genera also show a marked tendency to include or become incrusted with numerous foreign particles, which gives them a more or less agglutinated appearance. These particles are varied and may consist of extremely fine mineral grains or coccoliths produced by microscopic planktonic algae.

The relative proportions of the loricas, the form (dentate or smooth) or the oral collars, the shape and size of the oral openings, the presence of rings or rims around the tests, and the direction and anastomosis of longitudinal striae are other characters on which the present systematic arrangement of this group is based. According to Kofoid and Campbell, size is rarely distinctive as it is generally correlated with temperature and varies considerably within the geographic area of each species.

Only rarely can the standards and methods of planktologists working with living material be applied to fossil species, especially to those, like the Calpionellae, preserved by calcite in sedimentary rocks, although they can be used for Tintinnids preserved in chert. In thin sections of rock, however, nothing can be seen but the simple, more or less well preserved, outlines of the loricas, most of which retain nothing of their characteristic detailed structure. These silhouettes appear white in contrast to the gray color of the enclosing rock. It is not possible to govern the orientation of the sections, because the of minute size of these organisms, and few sections are obtained following the longitudinal axis of the lorica, although this orientation is the most desirable and the only one that gives an unmistakable representation. For this reason I believe that one must be very prudent in distinguishing fossil species within this group, for it is easy to go astray in trying

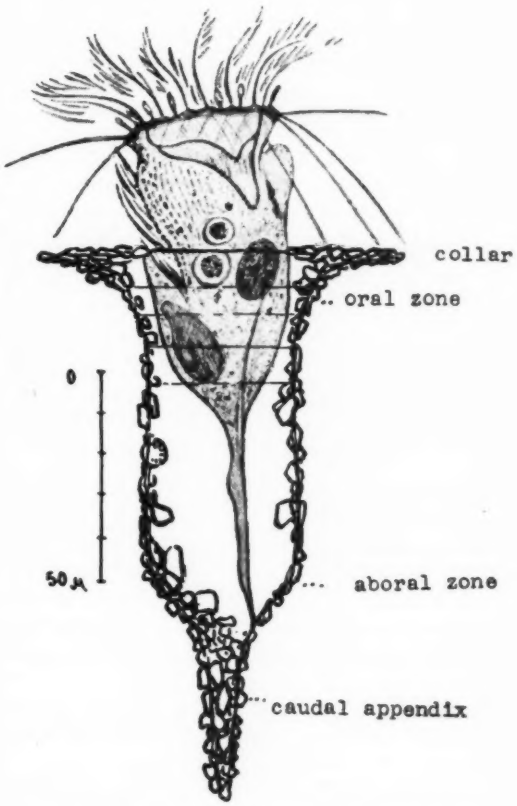


FIG. 1—*Tintinnopsis campanula* (Ehrenb.) after Fauré Fremiet, 1924. A living species, greatly enlarged, indicating terminology of the lorica.

to interpret the numerous random sections that are obtained. For example: sections of *Tintinnopsella carpathica* (Murgeanu and Filipescu) seem to show a considerable variety of loricas (fig. 2, a–c). Some are bell-shaped, with a wide oral opening; some are long and narrow and some have a globular apical region and a small oral opening. None reveals the existence of a caudal prolongation at the apical end. All, however, are the

same species but they are differently oriented.

An even more striking example occurs in a slide from the Tithonian of Cape Pinar, Alcudia (Majorca) which shows a lorica similar in shape to *Calpionella elliptica* Cadisch but differing from all other sections of this species in having a long caudal appendage, greater in length than the lorica itself (Fig. 11—*64*). Does this represent a species similar to *C. elliptica* but distinct because of its long caudal appendage? Or is such an appendage characteristic of *C. elliptica*, many of whose sections (Fig. 11—*65*, *67*, *68*, *73–75*) show a pointed and abruptly truncated extremity? It would be easy to accept the latter view, as the perfection of a section depends upon its orientation. The answer to this question, however, is even more involved. Professor Deflandre (1936) observed and figured a specimen of *C. elliptica* suggesting the existence of a cylindrical prolongation, or long neck, surmounting its oral opening (fig. 3, no. 27; text). Similar and even more perfect examples occur among my own slides and a particularly notable lorica appears in a section obtained from the Tithonian limestones of Cala Blanca, Andraitx (Majorca). This specimen is typically preserved and through the calcite granules can be seen, slightly blurred but unmistakable, a long cylindrical neck with a wide outward-turned lip at its outer and extending beyond the oral portion of a test of *C. elliptica* (Fig. 11—*72*). Professor Deflandre compared such specimens, with good reason, to living tintinnids of the genus *Codonellopsis* and especially to *Codonellopsis lusitanica* Jörg (Fig. 3, no. 28). If we compare the two sections just mentioned, the first with its long caudal appendage (Fig. 11—*64*) and the second with its long cylindrical neck (Fig. 11—*72*), with sections of *Calpionella elliptica* Cadisch showing the existence of a caudal appendage (Fig. 11, *65*, *67*, *68*, *73–75*), could they not all be assigned to a single species of the genus *Codonellopsis*? Quite possibly. However, if anyone should affirm that these different sections represent three distinct species, it would be difficult to oppose him with definite arguments, because differences of this kind are found among living forms and commonly they are described as different species. Consequently the "species" among fossil tintinnids may be understood quite differently according to the views of those who study them, a situation general to all ages and to very different groups of organisms, and I believe that the question of speciation among extinct tintinnids will always be a debatable one. This problem is nonetheless interesting, since these very facts are evidence that confirm the presence of true tintinnids in the beds of the Tithonian and Lower Cretaceous.

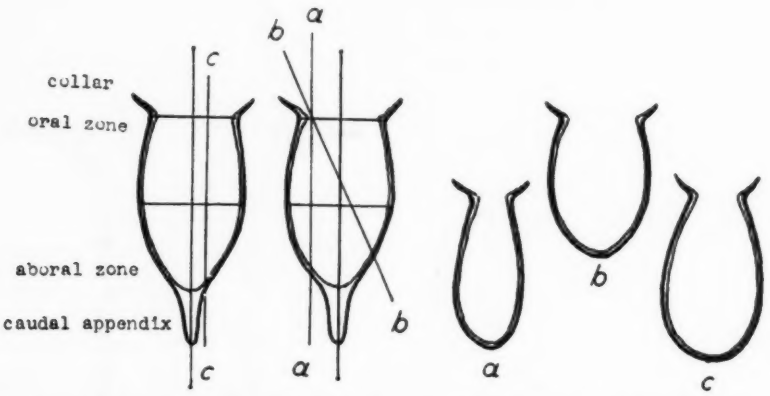


FIG. 2.—Drawings of *Tintinnopsella carpathica* (Murgeanu and Filipescu) showing how three different sections (*a*, *b*, *c* at right) might be obtained from a single form (*a*—*a*, *b*—*b*, and *c*—*c* on the two figures at left.) Greatly enlarged.

EARLY STUDIES OF FOSSIL TINTINNIDS

The Jurassic or Cretaceous cherts in which many admirably preserved microorganisms have been found (Dinoflagellata, Peridiniidae, etc.) have not yet furnished

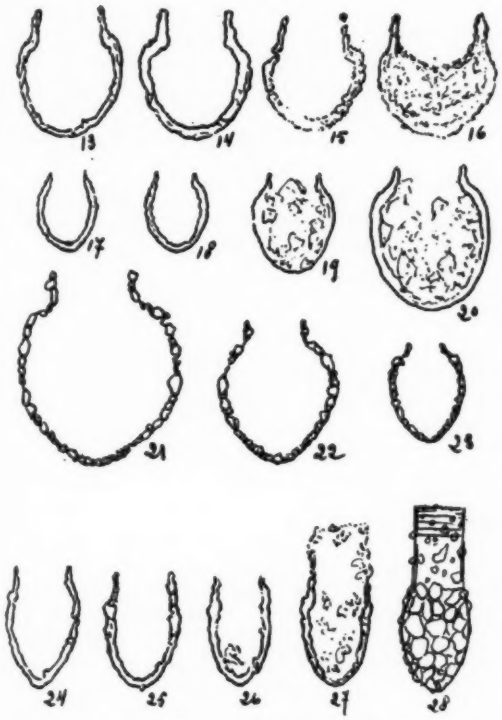

FIG. 3—Copies of figures *13* to *28* from Deflandre (Bull. Soc. Française de Micr., vol. 5, 1936). *13, 14, Calpionella alpina* Lorenz (Mesozoic, Alpine Tithonian Brunig); *15, 16* two tangential sections of *C. alpina* from the Alpine Tithonian, one (*15*) very oblique and showing an apparent lengthening of the oral collar, the other (*16*) very superficial and almost transverse to the upper level of an oblique lorica; *17–19*, small form of *C. alpina* from the Majorcan Hauterivian; *20*, *C. alpina* from the smal slide; *21, 22*, two extreme forms of the living *Stenosemella ventricosa*, longitudinal section; *23*, *S. nucula*, living species, longitudinal section. All figures ×250.

any examples of tintinnids. According to Deflandre (1936), however, the German paleontologist Rüst discovered tintinnid loricas in Jurassic rocks associated with Radiolaria. Such findings should be confirmed by new investigations.

Lorenz (1901) noted in the calcareous cement of the Falknis breach, pertaining to the uppermost levels of the Malm, numerous extremely small microorganisms of very simple structure. He compared them with similar fossils discovered by Steinmann in 1890 in the Jurassic limestones of the torrent of Morgorabbia in the southern part of the Alps and named them *Calpionella alpina*. Lorenz emphasized the stratigraphic importance of these microscopic forms as characteristic of the Vindelician facies of the Tithonian, belonging to the region of the "klippes" of Switzerland. In the following year, Kilian (1902) recorded the presence of *C. alpina* in the Swiss autochthonic series of the environs of Grenoble and wrote, "Le même auteur (Lorenz) a décrit sous le nom de *C. alpina* Lor., un petit foraminifère uniloculaire que se retrouve en quantité dans les calcaires a facies vaseux du tithonique Delphine-Provençal (Bastille, près Grenoble, Col de Cabre). Ces deux organismes peuvent être cités parmis les plus caracteristiques, le premier . . . le second (*C. alpina*) des calcaires tithoniques de la région subalpine." Steinmann (1913) cited these microorganisms in rocks both from the Carpathians and from Spain, localized likewise in Upper Jurassic and Lower Cretaceous strata.

Leon Moret (1925) noted the presence of *Calpionella* and numerous Radiolaria in a series of marly Tithonian limestones in the Isère Valley, near Grenoble. He did not indicate nor distinguish the species observed in his slides, but stated that the presence of tintinnid plankton seemed closely related to the purity of the marly sediment, which is strongly calcareous where they predominate.

In 1927 Andrussoff and Koutek devoted an extensive work to sediments with *C. alpina* Lorenz in the western Carpathians, thus verifying their wide dispersion throughout this zone. They mentioned only the one species, but stated that Radiolaria and *Calpionella* do not occur everywhere with equal frequency in the same strata. This observation is likewise true for their occurrence in strata of the same age in Majorca. The French geologist M. Solignac (1929) in a stratigraphic report recorded *Calpionella* in the Upper Jurassic of Tunis. At about the same time Professor E. Kraus (1929)

again called attention to the stratigraphic value of *C. alpina* and its significance as a type fossil of the Upper Jurassic. Professor J. Cadisch (1932) published an important work on *Calpionella* which includes a detailed study of *C. alpina* and descriptions of two new species, *C. elliptica* and *C. oblonga*. One chapter is devoted to a consideration of their stratigraphic and geographic distribution. This first comprehensive work on *Calpionella* is of great paleontological value. It called attention to these diminutive organisms and no doubt encouraged their investigation by others. The Roumanian geologists Murgeanu and Filipescu (1933) recorded a new species which is common in the Tithonian of the Carpathians of their country, *C. carpathica*. At about the same time another Roumanian, Dr. O. Protescu (1933) mentioned a new species which, so far as I am aware, has never been described and its name, therefore, is a *nomen nudum*.

LATER STUDIES OF FOSSIL TINTINNIDS

In writing on the Lower Cretaceous sediments of the Balearic Islands in 1930 and 1932 I noted the occurrence of *Calpionella* and reported on its vertical distribution in the stratigraphic series. In 1934, in a paleontological paper devoted to these microorganisms from the Balearics, I described a new species, *C. darderi*, summarized what was then known about the Calpionellae in general, and identified them with the loricated, planktonic infusorians of the family Tintinnidae of Claparède and Lachmann. Coinciding with the appearance of this study, an identical reference of *Calpionella* to the Tintinnidae was published in a bibliographical review in the "Palaeontologisches Zentralblatt" (Vol. 5, 1934–35) by Dr. Thalmann. Later, in his review of foraminiferal species published during the year 1933, Thalmann again drew attention to *Calpionella* as well as to another microorganism which is considered at the end of this paper. In this work Thalmann (1935) stated:

> The writer has suggested (he refers to the Palaeont. Zentr.) that the genus *Calpionella* should be removed from the Foraminifera and be classed within the family of the Tintinnidae (Ciliata). Colom, independently, arrived at the same conclusion (Soc. Esp. H. N. 1934).

The genus *Nannoconus* Kamptner, 1939, listed below, in the writer's opinion most probably represents what has been called by de Lapparent (1925) "embryons de Lagena." Thus *Nannoconus steinmanni* Kamptner becomes a synonym of *Lagena colomi* de Lapp, 1931.

Subsequently, study of the Calpionellae has attracted numerous investigators and increased interest in them has paralleled the modern intensification of interest in all kinds of fossil Protozoa. The widespread occurrence of fossil tintinnids in the pelagic faunas of the Tithonian and Neocomian throughout the Mediterranean Tethys has been revealed by the work of numerous geologists and they are now known to extend from the mountains of the Caucasus and Crimea, as reported by Vassoevitch in 1936, to the region of the Spanish Riff, where they were noted by Blumenthal in 1937.

Before the appearance of my note on *Calpionella* in 1934, the taxonomic position of these microoorganisms had been uncertain. They were assigned to the Foraminifera by some, to the Radiolaria by others, or considered to be an indefinite group of "incertae sedis." Dr. Galloway in his "Manual of Foraminifera," referred to the genus *Calpionella* with the remark, "This genus may be a calcareous alga." Dr. Cushman made no mention of them in the various editions of his well-known "Foraminifera." Dr. Kraus, in his study of 1929 previously referred to, denied the validity of the genus *Calpionella* and maintained that forms referred to it belong to the genus *Orbulina*, Foraminifera of the family Globigerinidae, which at the end of their development enclose all their early chambers of globigerinoid growth within a large, spherical, terminal chamber. He supposed that when the tests sank to the sea floor after death, gases formed by decomposition of organic matter within them broke through violently and formed the opening that is the oral aperture of the loricas. This supposition is of course, now untenable.

Professor A. Lombard of Switzerland devoted several papers (1937, 1945) to the study of a diminutive chlorophyllaceous alga belonging to the lowest and simplest groups, *Proto-* and *Pleurococaceas*, to which he gave the name of *Globochaeta alpina*. Its remains abound, according to this author

in certain pelagic Tithonian facies of the Alps. I have found these diminutive algae of Lombard's to be numerous in lower Tithonian strata of Majorca and probably at certain times they constituted an important part of the plankton of that epoch. Lombard believes that the numerous tintinnid loricas which are locally associated with *Globochaeta* represent a phase in the reproductive cycle of the latter (empty zygotes abandoned after sporulation).

I think this is not a reasonable conclusion. The loricas of the very different tintinnid species described and figured in the present work show such diversity of structure that it does not seem possible to interpret them all as simple zygotes, spores etc. of *Globochaeta alpina*. Moreover, the morphological similarities of fossil and living tintinnid loricas seem to me so close and definite that I am content to leave judgment in this matter to the reader.

### THE WORK OF PROFESSOR DEFLANDRE

In the "Bulletin de la Société Microscopique de France," Professor Deflandre (1936), well-known author of numerous works on living and fossil Protozoa, agreed with my opinion that the Calpionellae belong to the group of pelagic infusoria of the family Tintinnidae which is well represented in existing seas. In this work, revisional and critical rather than a contribution of new data, he stated that the tintinnids most likely to be fossilized are those having richly agglutinated loricas, and explained the possible process of their fossilization.

One of the most disputed and difficult points in admitting the existence of fossil tintinnids in Mesozoic sediments concerns the explanation as to how it has been possible for the delicate organic loricas of these planktonic infusoria to persist embedded in fine mud until they were replaced by calcite. As I have already stated, much has been published on the morphology of the loricas of living species but it is remarkable how little is known about their actual chemical composition.

Professor Deflandre believes that only loricas containing agglutinated particles could become fossilized in beds of highly calcareous ooze and that completely organic loricas can have left no trace in such strata. He compares species like *Calpionella alpina* Lombard and *C. elliptica* Cadisch with existing forms of the genera *Codonella*, *Codonellopsis* and *Stenosemella*, many of whose species have tests laden with agglutinated particles, and his drawings of thin sections suggest that such a conclusion is substantiated by observed structures. He also compares forms similar to *Calpionella carpathica* Murgeanu and Filipescu with various existing species of the genus *Tintinnopsis*, whose loricas are covered with minute grains of sand, etc. Such loricas, deposited with enormous numbers of the diminutive discs of *Coccolithoforidae* in the extremely fine Tithonian-Neocomian oozes would be rapidly buried and soon fossilized by the action of abundant calcium carbonate.

I have noticed some *Calpionella* loricas, which I included in 1939 in the genus *Favelloides*, that show extremely delicate structure when highly magnified. Within the thin mass of calcite of uniform optical orientation which reveals no grains, it is possible to distinguish a series of very fine, compressed partitions, transverse to the axis of the test, apparently similar to structures described by different investigators for certain living species. These are not uniformly orientated calcite crystals formed on the lorica walls such as occur on many specimens but rather an arrangement within the calcite which certainly reveals the primitive structure of the lorica. These observations, I believe, indicate the possibility that rapid replacement of the delicate primary structure of loricas lacking agglutinated material may have occurred, although I must admit that such preservation is not abundant among the innumerable sections of fossil tintinnids that appear in my slides. Although agglutinated tests are more likely to have been fossilized in Mesozoic strata, I am convinced that under certain conditions completely organic loricas have been replaced by calcite. This is not the only example that paleontology offers of delicate soft parts being replaced in such a manner.

Deflandre compares *Calpionella alpina* Lorenz with the existing species *Stenosemella ventricosa* (Claparède and Lachmann), common in the Mediterranean plankton, whose loricas are abundantly covered with

grains of quartz or calcite. He also found in the Tithonian limestones of Majorca a form of *C. alpina* characterized by its small size and comparable for that reason to another existing species of the same genus, *S. nucula*, with which it coincides in shape and dimensions. These comparisons are very convincing and for that reason I reproduce his drawings (fig. 3). Also, according to the same author, *Calpionella elliptica* Cadisch presents, as I have pointed out above, a strange analogy to *Codonellopsis lusitanica* Jörgensen of the existing plankton. This modern genus, and especially this species of Jörgensen, has a strongly arenaceous lorica continued by a long hialine neck which also may be covered with sand granules. Except for this neck *Codonellopsis lusitanica* bears an extraordinary resemblance to the fossil loricas of *Calpionella elliptica*, as is clearly shown by Deflandre's figures reproduced here (fig. 3). The resemblance between these two species is even more striking if one takes into consideration the existence of specimens of *C. elliptica* possessing a hialine neck (more or less blurred but unmistakable) such as Deflandre has figured and I have described above and illustrated by fig. 11—*72*.

*Calpionella carpathica* Murg.-Filip. is compared by Deflandre with different species of the genus *Tintinnopsis*, especially with *T. schotti*, *T. orientalis* (Fig. 10—*11*) and *T. loricata* (Fig. 10—*4*). All these living species have agglutinated loricas which could be fossilized in calcareous sediments. Also they all have oral openings similar to that of *C. carpathica*.

Professor Deflandre points out that he does not make these comparisons to suggest the identification of fossil forms with living ones, but only to emphasize the identity of structures in fossil Mesozoic Calpionellae and living tintinnids. He states: "Les calcaires a Calpionelles sont donc des calcaires a Tintinnoidiens." And in concluding his paper he remarks: "Est-il désirable d'appliquer dès maintenant aux Tintinnoidiens fossiles les noms des genres actuels? Je ne le pense pas, car les biologistes eux-mêmes ne sont pas encore entièrement d'accord sur l'acceptation de ces derniers. Disons seulement que les genres actuels *Tintinnopsis*, *Codonellopsis* et *Stenosemella* florissaient déjà vers la fin de l'époque jurassique et reservons encore quelque temps aux espèces fossiles le nom de Calpionella, en évitant bien entendu de créer abusivement des genres nouveaux pour les Tintinnoidiens fossiles. Il reste, c'est bien certain, d'autres espèces de Calpionelles a découvrir."

I have no desire to complicate the systematic arrangement of fossil tintinnids (in this I agree with Professor Deflandre) but it has been necessary to create new genera. Upon the discovery in 1939 of fossil loricas whose characters coincide perfectly with those of the living genera *Favella* and *Rhabdonella*, I decided to propose two new fossil genera, *Favelloides* and *Rhabdonelloides*, because it did not seem prudent to include them in Lorenz' primitive genus *Calpionella*, which they do not resemble. In continuing this study, it has not seemed advisable to include in *Calpionella* a series of newly discovered loricas whose structural features differ greatly from those characteristic of that genus. Accordingly, I have been obliged (Deflandre anticipated this would be necessary) to alter the whole systematic arrangement of this group, adapting it to the newly discovered fossils and also to our present knowledge of all the species described. For that reason I have distinguished a few new genera and have distributed the species in different groups according to their more notable affinities but I have retained in Lorenz' genus, *Calpionella*, the forms most intimately related to *C. alpina*, the type of this genus. I have been careful not to distinguish numerous species because of the uncertainties previously discussed.

Before describing new genera and species I have studied, whenever possible, numerous well-oriented sections in order to minimize the possibility of basing determinations on differently oriented sections or deformed specimens. With few exceptions, new species are abundant at certain particular Balearic localities.

The data presented by Deflandre and my own investigations have profoundly modified concepts regarding the morphology of the loricas of these fossils and their systematic arrangement. With the new information presented here, the simplicity of the earlier classification of the Calpionellae,

when only five species—*C. alpina*, *C. elliptica*, *C. oblonga*, *C. carpathica*, *C. darderi*—were known, disappears and a group of well defined but quite variable organisms becomes apparent that is similar to a living group now inhabiting marine waters in great abundance.

The systematic strictness of definition and description used by investigators of the living animals cannot be applied to fossil material preserved as calcite replacements in limestone. The Tithonian or Neocomian fossils of Majorca do not provide the micropaleontologist with as exact and conclusive data as might be desired and ample margin for varied interpretations of certain features will always remain. A study of all the species described in the following pages reveals the existence of a large group of organisms exhibiting great specific and generic diversity of structures which would be classified by planktologists in many different groups. A similar classification of fossil specimens, however, is not possible because the fine structural details of the Tithonian or Neocomian loricas have mostly been destroyed and the simple outlines that remain are not easy to interpret.

## DESCRIPTION OF GENERA AND SPECIES

### Genus CALPIONELLA Lorenz, 1901

Genotype, *Calpionella alpina* Lorenz

This genus includes those species whose loricas are morphologically similar to Lorenz' type species, *C. alpina*.

Lorica globular, oval or cylindrical, usually rounded at the aboral end but in some specimens pointed. Certain species have an oral collar extending straight forward from the lorica and a thickening of the test near its point of insertion, but in others the collar is wanting.

### CALPIONELLA ALPINA Lorenz, 1901

Figure 11—*1*, *22–33*, *35–43*

*C. alpina* LORENZ, 1901, Geolog. Stud. Grenzg. Zwischen Helv. Ostalp. Faz., Naturf., Ges., Freiburg.—CADISCH, 1932, Geolog. Rundschau vol. 23, p. 248, figs. 1–2 (text) and fig. 3 (text), no. 1–9.—COLOM, 1934, Bol. R. Soc., Española Hist. Nat., vol. 34, p. 380, pl. 30, figs. 1–3.—DEFLANDRE, 1936, Bull. Soc. Française Microscop., vol. 5, p. 116, figs. 13–23.—COLOM, 1939, "Las Ciencias" Año 4, no. 4, p. 8.

The more typical specimens of *C. alpina* have spheroidal loricas with rather prominent, forward projecting collars. The walls are thin, somewhat sinuous and tend to narrow slightly at the lowered end of the lorica (Fig. 11—*22–26*, *31–33*, *35*, *36*) other specimens are more oval in section or even almost elliptical (Fig. 11—*28*, *40–42*. In both groups loricas with more or less pointed aboral portions have been observed but I have found none with any clearly visible caudal prolongation, such as occurs in other species.

The largest loricas measure 110$\mu$ in length by about 80$\mu$ in width but are rather exceptional. A common average is 80$\mu$ in length by 60$\mu$ in width but forms 70 by 55$\mu$ are nearly as abundant. Measurements of 31 typical specimens may be grouped as follows:

| Length of the lorica | 50–60 | 60–70 | 70–80 | 80–90 | 90–100 | 100–110 | microns. |
|---|---|---|---|---|---|---|---|
| Number of specimens | 1 | 6 | 3 | 12 | 6 | 0 | 2 |

Two modes are apparent, one at about 60$\mu$ and another, more prominent, between 80 and 90$\mu$. Width measurements show corresponding modes at 40 and 60$\mu$, of which the former is more prominent. These data might reasonably justify the distinction of two races in *C. alpina*, as Deflandre has suggested but to determine adequately variations within this species a much larger number of individual measurements are required.

The study of large populations of *C. alpina* seems to confirm the existence of a diminutive race of this species. Deflandre compared it to the living species *Stenosemella nucula* (Fol.), which is always found associated with *S. ventricosa* (Clap.-Lach.), of larger size. Figs. 11—*22*, *23*, *28*, *38*, *39* illustrate various specimens of this small form. The smallest loricas are 43$\mu$ long by 38$\mu$ wide. These measurements differ somewhat from those given by Deflandre which vary from 35 to 47$\mu$ in length. Most of his specimens measure about 50 by 40$\mu$ (fig. 3, text).

In considering the possible existence of a small race, it must not be forgotten, however, that many small lorica sections may correspond to somewhat tangential cuttings of loricas of normal dimensions.

*Calpionella alpina* is common in tintinnid-

bearing facies. Its tiny, horse shoe-shaped sections appear white against the greenish-gray matrix of the sediment. This species seems to be very widely distributed in the Tithonian of the Mediterranean region.

CALPIONELLA ELLIPTICA Cadisch, 1932
Figure 11—*2, 51–81*

*C. elliptica* CADISCH, 1932, Geol. Rundschau. vol. 23, p. 241, fig. 3 (text), n. 10–11, 17, 25–26. —COLOM, 1934, Bol. R. Soc. Española Hist, Nat., vol. 34, p. 380, pl. 30, figs. 4–6.—COLOM, 1939, "Las Ciencias," Año 4, no. 4, p. 8.—DEFLANDRE, 1936, Bull. Soc. Française Microscop., vol. 5, no. 3, p. 118, figs. 24–26 (text).

In general characters this species is closely related to the last. It has the same oral zone and collar. It differs from *C. alpina*, however, in having a longer lorica, with parallel sides, which gives the whole test an elliptical form in section. In many specimens the aboral zone is pointed and seems to reveal the existence of a caudal extension (Fig. 11—*65–68, 73, 75–77*). This supposition seems well founded if one takes into account the specimen with characters typical of *C. elliptica* figured in Figure 11—*64*, and provided with a long caudal appendage.

The largest specimens of *C. elliptica* measure 110$\mu$ in length by 56$\mu$ in width but they are not common. Those that appear in greatest abundance reach a length of about 85$\mu$, and a width of 50$\mu$. The smallest are about 60 by 38$\mu$ respectively.

This species almost always is associated with the last but I agree with Dr. Cadisch that there are no intermediate forms. The size distribution indicates that *C. elliptica* is a very homogenous group with only a single mode.

The measurements of 31 specimens are grouped as follows:

| | |
|---|---|
| Length of the lorica | 50–60–70–80–90–100 microns. |
| Number of specimens | 2– 4– 4–13– 6– 2 |
| Width of the lorica | 30–40–50–60 microns. |
| Number of specimens | 10–11– 8– 3 |

The figures of the two species, *C. alpina* and *C. elliptica*, (Fig. 11) show this constancy clearly. Although certain sections may not appear so distinctive, it must be remembered that if they are not cut parallel to the longitudinal axis of the lorica slight discrepancies will result.

As previously mentioned, some specimens of *C. elliptica* show traces of a long, more or less altered, cylindrical neck, set upon the oral collar. Deflandre in his paper of 1936 figured a specimen of this kind (fig. 3, no. 27; text) from the Alpine Tithonian and my slides from Majorca also show sections with similar structures. In one of my sections the neck is very complete (Fig. 11—*72*) and flaring at its free end. It is shown by a series of fine calcite granules, faintly marking its outline and is not as clear as the rest of the lorica but there can be no doubt as to its existence or interpretation (fig. 3, no. 27).

It might be possible to completely reconstruct this species on the basis of the three different but related kinds of loricas (with or without a caudal prolongation, or with a long cylindrical neck) and classify it as a species of the existing genus *Codonellopsis* very close to the living species *C. lusitanica* Jörgenson, as Deflandre has done. If so it would be the first exact reconstruction of a fossil tintinnid but certain doubts would necessarily remain. Therefore I consider it inadvisable to separate this species from its original genus by transfering it to *Codonellopsis*, and I only wish to point out how reasonable Professor Deflandre's comparisons seem to be, in view of the new information furnished by my Balearic material.

*C. elliptica* is commonly present in the upper strata of the Tithonian and in the Berrasian of Majorca.

CALPIONELLA UNDELLOIDES Colom, 1939
Figures 11—*3, 34, 47, 49, 55*

*C. undelloides* COLOM, 1939, "Las Ciencias" Año 4, no. 4, p. 6, pl. 2, fig. 12.

This is a small species with an oval lorica

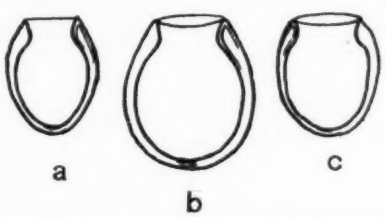


FIG. 4—*Undella claparedei. a, U. claparedei* form *angustior* Jörgensen; *b, U. claparedei* (Entz) Daday, after Jörgensen; *c, U. claparedei* form *fastigata* Jörgensen. Median longitudinal sections.

showing in its oral region the presence of a collar formed by the thickening of the oral edges of the lorica. It is very similar to living forms of the genus *Undella* Daday (fig. 4). Length about 50$\mu$, width 34$\mu$. Somewhat larger specimens have also been observed.

A few specimens of this species have been found associated with large numbers of *C. alpina* and *C. elliptica* in the Tithonian of the Farrutx Mts., Artá Majorca.

This species is very similar to other true calpionellids and may be confused with them if the specimens are not well preserved. However, it never has the projecting oral collar of *C. alpina* or *C. elliptica* and the oral region ends without a neck and with no alteration in the smooth oval line of the outer lorica wall, but inwardly the wall is thickened in the oral region. Figures of this species might be mistaken for specimens of *C. alpina* which lack an oral collar but loricas of this type have never been observed with any trace of a projecting collar.

CALPIONELLA MASSUTINIANA
Colom, n. sp.
Figure 11—*45*

Lorica elongate, conicocylindrical, showing in some specimens the possible existence of a caudal prolongation. Oral region typically surrounded by a bulging ring just posterior to the oral collar. This feature distinguishes it from the other species of the genus. The loricas are about 80$\mu$ in length and about 45$\mu$ in width as measured at the center of the lorica.

This species occurs in certain zones of the Tithonian and at the base of the Valanginian of Majorca. Although not common it is widely distributed through all the deposits of these ages of the island.

Genus CALPIONELLOPSIS Colom, n. gen.
Genotype, *Calpionella thalmanni* Colom

Long cylindrical loricas, pointed or rounded at the aboral ends and provided with very simple straight anteriorly projecting oral collars which do not widen or flare outwards.

The two species *C. simplex* and *C. thalmanni*, for which this new genus is created, are too different from true *Calpionella* to be included in that genus. Their loricas are delicate, with thin walls and generally much larger than in true *Calpionella*. The oral openings are so different in these two species there may be some question that they should be included in the same genus.

CALPIONELLOPSIS cf. THALMANNI
(Colom) 1939
Figure 11—*7*; 12—*36*

*Calpionella thalmanni* COLOM, 1939, "Las Ciencias" Año 4, no. 4, p. 7, pl. II, fig. 17.

Lorica elongate, cylindrical, conical at its aboral end and rather pointed in nearly all specimens studied; lowest third more or less markedly dilated, then narrowing towards the oral opening. The collar shows clear traces of a very typical inward thickening. Length of lorica generally about 100$\mu$, width about 40$\mu$ at the aboral dilation and 30$\mu$ near the oral opening.

This species has been found only in the Valanginian-Hauterivian of the Farrutx Mts., Artá, Majorca and, although it is not rare, neither is it common in any zone at that locality. It is easily distinguished from *C. simplex* by its elongated form and typical inwardly thickened collar.

CALPIONELLOPSIS SIMPLEX
(Colom) 1939
Figure 11—*10*

*Calpionella simplex* COLOM, 1939, "Las Ciencias" Año 4, no. 4, p. 6, pl. II, fig. 11; pl. 3, fig. 9.

Lorica cylindrical, widening slightly towards its aboral end, which is rounded. The oral collar is very simple and marked by a small inner furrow visible in all well-preserved specimens. Loricas commonly attain a size of about 90$\mu$ in length by 40$\mu$ in width. The simple structure of the oral collar distinguishes this species from allied forms and seems to be very constant.

Well-preserved specimens have been found in the Neocomian in the region of Puigpunyent (Majorca) where it is not rare. Others occur in slides from the hermitage of La Victoria, Alcudia, Majorca, especially from Valanginian strata.

Genus CALPIONELLITES Colom, n. gen.
Genotype, *Calpionella darderi* Colom

This genus includes species with loricas that are spheroidal, bell-shaped, or elongate

and cylindrical. The aboral end tends to form a point and possibly is continued by a caudal appendage. The most typical character, and the one that distinguishes this genus from others, is the structure of the oral collar which, during the life of the infusorian, must have consisted of a double inner wall around the opening, and shows in sections of fossil loricas as a clearly bifurcated termination of the wall.

### CALPIONELLITES DARDERI (Colom)
Figure 12—*1–15*

*Calpionella darderi* COLOM, 1934, Bol. R. Soc. Española Hist. Nat., vol. 34, p. 381, pl. 31, fig. 3. —COLOM, 1939, "Las Ciencias" Año 4, no. 4, p. 8, pl. 3, fig. 7.—DEFLANDRE, 1936, Bull. Soc. Franç. Microscop., vol. 5, no. 3, fig. 5.

Lorica generally bell-shaped with a large oral opening; rarely tending toward a cylindroid shape. The most typical character of this species is the shape of its oral collar, which has a terminal bifurcation usually directed slightly inwards. The aboral edge of the lorica is rather variable, it may be more or less sharpened but more commonly it is rounded. The size of typical specimens averages about 100$\mu$ in length by 80$\mu$ in width, but there are smaller loricas whose dimensions vary around 80$\mu$ in length by 68$\mu$ in width.

Some large specimens of this general type attain sizes of from 115 to 130$\mu$ in length by 65 to 70$\mu$ in width. These are cylindroid loricas, generally pointed aborally, whose width scarcely varies in spite of their excessive length. They also possess very wide oral openings with bifurcated collars. The ratio of their dimensions is very constant and separates them from the typical *C. darderi*. The three specimens illustrated by fig. 12—*6–8* do not fall within the range of typical *C. darderi* and are distinguished as *C. darderi major* Colom, n. var.

The first specimens of *C. darderi* were found in the Neocomian limestones of the island of Ibiza (Balearics), collected from the north slope of Mt. Rado near Cala Llongue. Later others were found in the fine Valanginian-Hauterivian limestones of Cape Pinar (Alcudia, Majorca) where they are abundant.

### CALPIONELLITES NEOCOMIENSIS
Colom, n. sp.
Figure 12—*16–18, 22–24*

These loricas are distinct from *C. darderi*, but because of their poor preservation they are not easy to characterize.

Loricas rather cylindrical, elongate, with the aboral edges rounded. Such specimens are illustrated by fig. 12—*21–24* and reach a size of 110$\mu$ in length by about 42$\mu$ in width but others are more oval and smaller, about 90$\mu$ in length by 80$\mu$ in width. All are similar, however, in having a very peculiar oral collar which is incompletely preserved and difficult to interpret, so that it is impossible to obtain a clear idea regarding its original structure. Such remains of this collar as are preserved seem similar in type to that of *C. darderi*. The best preserved specimen (Fig. 12—*23*) shows the existence of a terminal bifurcation or double wall whose inner branch, perhaps the better preserved, is the better developed. In many sections, however, only a small fragment of the terminal bifurcation remains and it is almost always separated from the lorica.

Specimens of this species occur in many Neocomian beds in Majorca, but it is nowhere abundant.

## Genus STENOSEMELLOPSIS Colom, n. gen.
Genotype, *Calpionella hispanica* Colom

Loricas generally oval, with thin walls which turn inward abruptly to form a simple usually narrow, oral opening without any kind of collar. The most common type corresponds to fig. 12—*30*.

### STENOSEMELLOPSIS HISPANICA
(Colom) 1939
Figure 12—*27–30, 32, 33, 37, 39*

*Calpionella hispanica* COLOM, 1939, "Las Ciencias" Año 4, no. 4, p. 6, pl. 2, 13 (not fig. 14).

Lorica generally oval and rounded aborally but some specimens (Fig. 12—*28*) are somewhat pointed. In the oral zone, the walls tend to continue the oval of the section and in some the opening is very narrow. Sections that do not show this character result from faulty orientation or some defect (Fig. 12—*29, 32*). One specimen that I have seen shows traces of a bifurcation of the

lorica wall at its oral end (Fig. 6—*37*). Most specimens average about 90$\mu$ in length by 80$\mu$ in width but some are smaller and a few rare ones attain 130$\mu$ in length and 100$\mu$ in width.

Median longitudinal sections of *Stenosemella ventricosa* (Claparède and Lachmann) Jörgensen (Fig. 10—*5*) of the existing plankton are very similar to sections of this species.

*S. hispanica* occurs in Neocomian strata of Majorca in the region of Calvia and Andraitx, but the details of its stratigraphic distribution are not known. It is also present in the Valanginian-Hauterivian at the hermitage of La Victoria, Alcudia, Majorca.

## Genus TINTINNOPSELLA Colom, n. gen.
Genotype, *Calpionella carpathica* Murgeanu and Filipescu

The species referred to this genus are intimately related to the family Codonellidae of Kent as this is now understood and their morphological similarity to *Tintinnopsis* Stein 1867 is evident as noted by Professor Deflandre in 1936.

The loricas of living *Tintinnopsis* are rather variable in shape—cylindrical, bell-shaped etc.—but they all have large oral openings whose rims may be turned outwards. The tests are mostly covered with densely agglutinated foreign particles. A caudal appendage may be present. In spite of their similarity it is impossible to determine if the Tithonian or Neocomian species should be assigned to *Tintinnopsis*. For this reason, I am proposing a new genus for the fossil species.

Lorica bell-shaped or cylindrical, with thin walls. Aboral region rounded, pointed or prolonged into a more or less long caudal appendage. Oral zone with a large aperture which may equal the greatest width of the test, with a conspicuous laterally directed collar.

### TINTINNOPSELLA CARPATHICA (Murgeanu and Filipescu) 1933
Figures 11—*8*, 13—*1–56*

*Calpionella carpathica* MURGEANU and FILIPESCU 1933, Notat. Biologicae, vol. 1, no. 2, Bucarest, fig. 1, a, b, c (text).—COLOM, 1934, Bol. R. Soc. Española Hist. Nat., vol. 34, p. 381, pl. 30, figs. 7–9.—COLOM, 1939, "Las Ciencias" Año 4, no. 4, p. 8.

*Favelloides majoricensis* COLOM, 1939, "Las Ciencias" Año 4, no. 4, p. 5, pl. 1, figs. 5–8; pl. 3, figs. 2 and 10.

The figures of *Calpionella carpathica* given by its authors in their original publication seem to be conventional or schematic rather than exact reproductions of sections in their slides. However, their form C clearly reveals

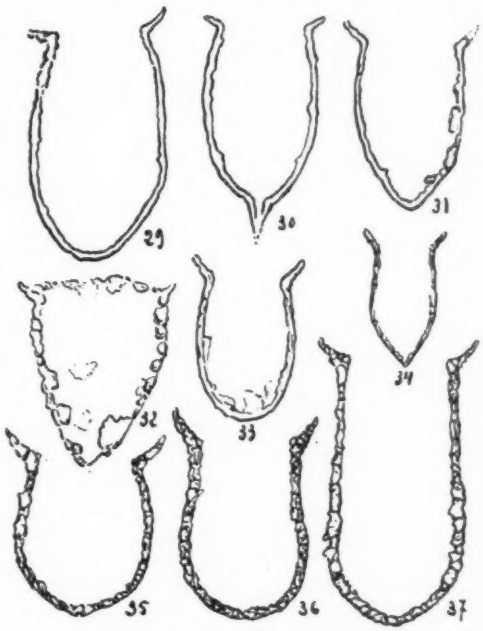


FIG. 5—Copies of figures *29* to *37* from Deflandre (1936). *Calpionella carpathica* Murgeanu and Filipescu from the Mesozoic, and several living species of *Tintinnopsis*. *29–33*, *C. carpathica*, Hauterivian of Majorca: *29*, large form with rounded aboral end; *30*, form with caudal prolongation; *31*, form with pointed end; *32*, form widely pointed, with traces of an operculum in the oral zone; *33*, small rounded form. *34*, *T. balthica* Brandt; *35*, *T. schotti* Brandt; *36*, *T. orientalis* Kofoid and Campbell; *37*, *T. loricata* Brandt. Median longitudinal sections. ×250.

the typical characters of this species as it is represented in Balearic sediments and I have recognized this species in numerous Tithonian and Lower Cretaceous beds of Majorca and southeastern Spain. Figures 13—*32–56* can be referred to it. As so determined its characters are: lorica bell-shaped or cylindrical, with thin walls, aboral end rounded, oral

opening large. The oral collar opens outwards in a typical manner.

This species is very abundant in Majorca and I have been able to study numerous specimens, many of which are illustrated here. In such a large number of specimens some occur which are identical with *C. carpathica*, except that they clearly show the presence of a caudal appendage at the aboral end. In 1939 I described such specimens as *Favelloides majoricensis* but after further study I am convinced that it is impossible to separate them from *Calpionella carpathica*. Transition forms are very numerous and all gradations occur from loricas of *C. carpathica* with more or less pointed aboral ends (Fig. 13—*48–56*) to those with distinct caudal appendages, of which figure 13—*11*, *18*, *20* are especially notable and characteristic. As I have explained, if the sections are not perfectly oriented a great variety of forms appear which may or may not indicate the presence of a caudal appendage.

The dimensions of *Tintinnopsella carpathica* are rather variable. The largest, and also the more cylindrical and elongate specimens, measure about 110$\mu$ in length by 53$\mu$ in width. Other smaller ones are about 100$\mu$ by 50$\mu$. Still others, quite small by comparison, 60$\mu$ in length by 46$\mu$ in width, are common, but their small size cannot be attributed to random sectioning because some of them show the beginning of a caudal appendage and thus prove that they are cut close to the longitudinal axis of the lorica (Fig. 13—*53*, *54*). In general, loricas 90$\mu$ in length by 50$\mu$ in width are most common. The caudal appendages vary from 30 to 40$\mu$ in length.

This species shows undoubted affinities with the modern genus *Tintinnopsis* and some of my figures may be compared with the living species *T. campanula* (Ehr.) Daday and *T. balthica* (Claparède and Lachman). Among the 56 figures of *Tintinnopsella carpathica* on figure 13, there is a number of forms whose characters might serve to distinguish them as different species by the standards of modern planktologists and some of them might be identified with living species, but the recognition of fossil species is much more difficult and uncertain and I do not think that justification for separating them exists.

I have investigated the possibility that, among large populations of *T. carpathica*, variations characteristic of successive stratigraphic zones might be recognizable but have not found this to be so. Both large and small forms and those with or without a caudal appendage appear to occur irregularly throughout the entire section. For that reason also I have not wished to create new species.

This species is very common in all of the Lower Cretaceous of Majorca, Ibiza and southeastern Spain and it persists into the youngest strata of Majorca, being found even in the Barremian zones of the island.

### TINTINNOPSELLA OBLONGA (Cadisch) 1932

Figures 11—*13*, 13—*57*, 14—*5*

*Calpionella oblonga* CADISCH, 1932, Geol. Rundschau, vol. 2, p. 252, figs. 20–21.—COLOM, 1934, Bol. R. Soc. Española Hist. Nat., vol. 34, p. 381, pl. 31, figs. 1–2.—COLOM, 1939, "Las Ciencias" Año 4, no. 4, p. 8.

Lorica elongate, cylindrical, aboral portion widest and rounded, gradually narrowing toward oral opening with laterally extended collar. This species averages about 110$\mu$ in length by 40$\mu$ in width (Fig. 14—*5*) but some much larger loricas occur (Fig. 13—*57*, measures 160$\mu$ by 53$\mu$).

The original description of this species makes no mention of an oral collar and none was figured by Cadisch. Sections of this type occur in my slides but they are connected by transitional forms with others possessing distinct and well preserved collars. The original description probably was based on poorly preserved specimens.

*T. oblonga* has been found only in the Neocomian limestones of Majorca, as at Bendinat (near Palma), hermitage of La Victoria (Alcudia) and the Farrutx Mts. (Artá), where it is associated with other species. It is not abundant.

### TINTINNOPSELLA LONGA (Colom) 1939

Figures 14—*2–4*, *6–8*

*Calpionella longa* COLOM, 1939, "Las Ciencias" Año 4, no. 4, p. 5, pl. 2, fig. 9 and pl. 3, fig. 3.
*Calpionella cylindrica* COLOM, *ibid.*, p. 7, pl. 2, figs. 15–16 and pl. 3, fig. 8.

Lorica elongate, walls nearly parallel

although some specimens may be slightly distended at the aboral end. Oral region with turned out collar and an opening almost as wide as the diameter of the lorica. This species undoubtedly had a caudal appendage but none of my sections shows it clearly because of imperfect orientation.

Some small specimens, about 120$\mu$ by 37$\mu$, are possibly related to *T. carpathica*. Other larger cylindrical loricas, 160 by 50$\mu$, certainly are not. The average size is about 145$\mu$ in length by 40$\mu$ in width.

After studying many more specimens of the types which I described as *C. longa* and *C. cylindrica* in 1939, I now consider that they represent a single species. Their loricas are similar in structure and size and the only difference is that *C. longa* has a pointed aboral extremity and perhaps ended in a caudal appendage, while *C. cylindrica* is completely rounded. Such characters are of negligible differential value.

This species is rather common and occurs with large numbers of *T. carpathica* in the Neocomian of the Farrutx Mts., Artá (Majorca) and also in the Lower Cretaceous of Cala Blanca, Andraitx (Majorca) in Barremian strata which are characterized by abundant pyritized ammonites. It has also been collected by Professor Bataller from Barremian ammonite-bearing limestones at Caravaca (province of Murcia, Spain).

TINTINNOPSELLA CADISCHIANA
Colom, n. sp.
Figures 12—*19–21*, *25*, *26*, *34*, *35*, *40*

CADISCH, 1932, Ein Beitrag. zum Calpionellen-Problem. Geol. Rundschau, vol. 23, fig. 3, no. 18–19.

This species was discovered and figured but not named by Dr. Cadisch in 1932.

In this species the oral end appears as though broken off and above it the collar lies at right angles forming a letter T, the horizontal line of which may be separated from the end of the lorica. These specimens are morphologically very constant. I have searched for individuals that might be transitional to *T. carpathica* or some other similar species to prove that such loricas might be deformed or badly-preserved but I have found none.

Two types of specimens can be distinguished in this species. Some are large, 160$\mu$ in length by 70$\mu$ in width, and others much smaller, 90$\mu$ by 70$\mu$. In both the loricas are wide. In the first type they are broadly cylindrical with walls parallel throughout their entire length but the smaller forms are more bell-shaped. In both, the aboral end is generally rounded but some specimens show the beginning of a caudal appendage as in Fig. 12—*26*, a large lorica, and 12—*40*, a small one.

Some loricas occur which lack a collar (Fig. 12—*19*, *20*) or show only fragments of one (Fig. 12—*21*). At present I consider that they belong to this species because, except for this detail, which may be a result of damage before fossilization, they correspond in both size and shape. Three of the figured specimens show clear traces of a caudal appendage.

This species is widely but irregularly distributed in the Neocomian of Majorca. Although nowhere abundant, it is characteristic of the youngest strata in this early Cretaceous series of the Balearics.

TINTINNOPSELLA DOLIPHORMIS
(Colom) 1939
Figure 11—*11*

*Calpionella doliphormis* COLOM, 1939, "Las Ciencias" Año 4, no. 4, p. 6. Plate 2, fig. 10.

Lorica widest in middle, narrowing gradually toward aboral end that is not sharply pointed, also narrowing towards the oral opening. Oral zone with a rather widely turned out collar and a very characteristic narrow constriction immediately below.

Specimens measure about 120$\mu$ to 130$\mu$ in length by about 52$\mu$ in greatest width. The opening is rather narrow, averaging 30$\mu$ in diameter. I have only a few specimens of this type in slides from the Neocomian beds of Alqueria Veya, Artá (Majorca).

TINTINNOPSELLA MAXIMA Colom, n. sp.
Figure 14—*1*

Only one specimen of this type has been found. It is a well preserved section almost in the longitudinal axis, from the very fine sublithographic limestone cropping out at the foot of the watch-tower at Cape Pinar, Alcudia. The strata at that locality contain

numerous ammonites, among which *Crioceras angulicostatus* Pict., a species generally indicating beds of Hauterivian-Barremian age, predominates.

The lorica is long and cylindrical. It is 200$\mu$ in length excluding the aboral appendage, nearly 90$\mu$ long, and the outward-turned portion which is imperfectly preserved and somewhat deformed, especially on the right side.

Among the existing species of the genus *Tintinnopsis*, *T. coronata* Kof.-Camp, attains a length of 250$\mu$ but has a very small oral collar. *T. panamensis* Kof.-Camp. is even larger, varying according to its authors from 275 to 330$\mu$ in length.

### TINTINNOPSELLA BATALLERI Colom, n. sp.
Figure 12—*54*, *55*

Lorica elongate, cylindrical, with rounded aboral end and a characteristic strong constriction just below the oral collar. Its dimensions average about 125$\mu$ in length by 35$\mu$ in width but smaller specimens are not uncommon.

This species occurs sporadically with other forms of *Tintinnopsella* in the Majorcan Neocomian. It is named in honor of Professor Bataller of Barcelona, who collected the first samples, very rich in tintinnids, of Barremian limestones from Caravaca (Murcia, Spain).

### Genus FAVELLOIDES Colom, 1939
Genotype, *Favelloides balearica* Colom

This fossil genus is very similar to existing *Favella* of Jörgensen in the shape and arrangement of its caudal prolongation and in the other characters of its lorica. The oral collar does not turn outwards as in *T. carpathica* but continues the direction of the lorica wall or turns outwards only slightly. The fossil species have not been included in Jörgensen's genus, as defined by its author, because it is impossible to determine some of the lorica characters. Some fossil specimens, when highly magnified, still show traces of the double lorica walls and their prismatic structure.

### FAVELLOIDES BALEARICA Colom, 1939
Plate 33, figure 18
Figure 11—*14*, *15*

COLOM, 1939, "Las Ciencias" Año 4, no. 4, p. 4, pl. 1, figs. 2–3; pl. 3, fig. 4.

Lorica goblet-shaped, very wide open at the oral end. Collar completely lacking. Caudal prolongation short. Test walls very thin and appear broken or incomplete in many of the sections. Most specimens measure about 120$\mu$ in length by 52$\mu$ in width at the center of the test and 70$\mu$ at the mouth but the size is variable and smaller specimens, about 100$\mu$ long, including the caudal appendage, are common. This species is not uncommon in the Valanginian and

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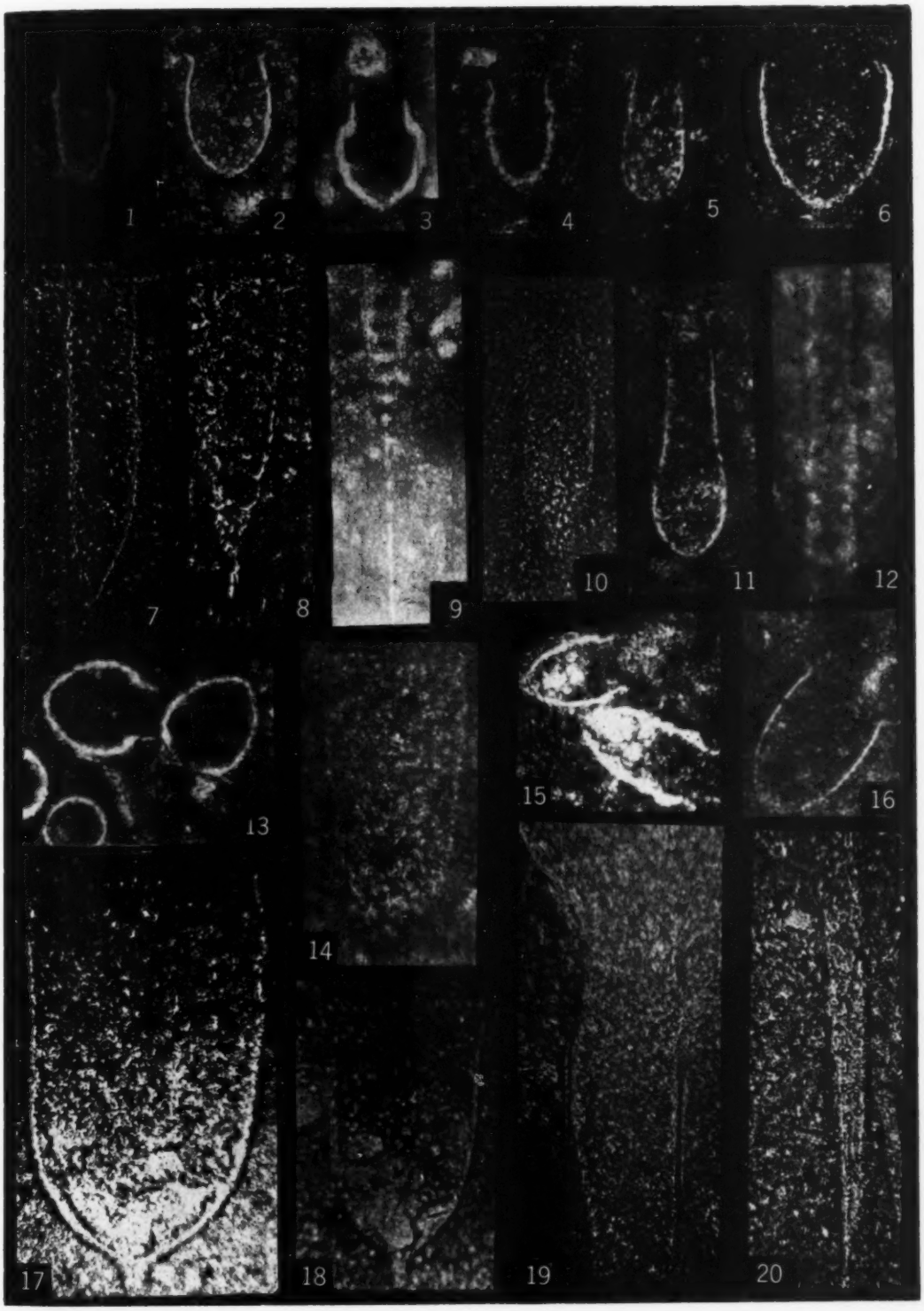
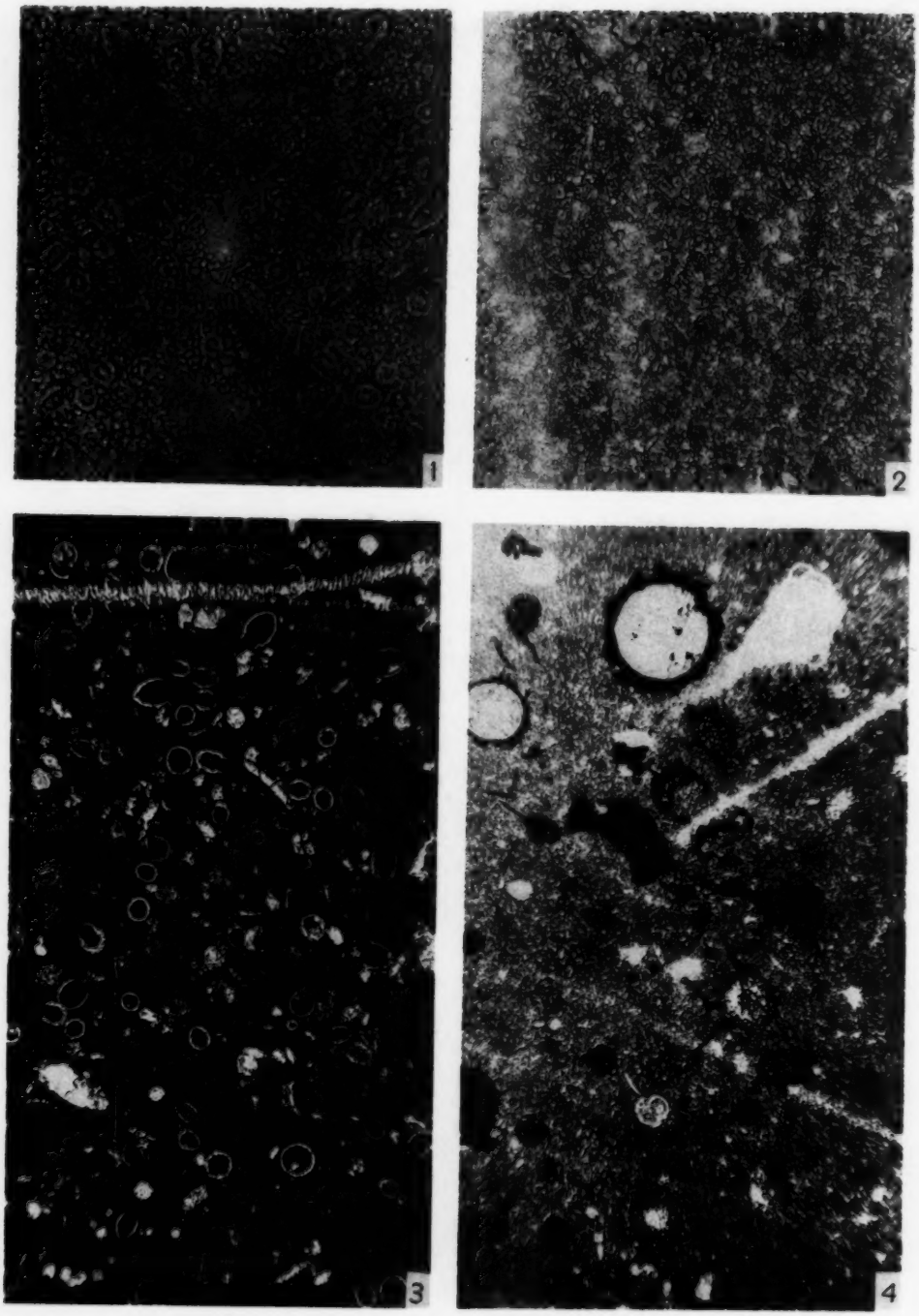
EXPLANATION OF PLATE 33

FIGS. *1*, *4*, *15*—(All figures are photographs of thin sections, ×500.)—*Calpionella elliptica* Cadisch, Tithonian of Majorca. Diminutive specimens. (p. 242)
*2*, *16*—*Tintinnopsella carpathica* (Murgeanu and Filipescu), Valanginian of Majorca. (p. 245)
*3*, *13*—*Calpionella alpina* Lorenz, Tithonian of Majorca. (p. 257)
*5*, *11*—*Tintinnopsella oblonga* Cadisch, Valanginian of Majorca. *5*, Specimen with oral extremity lacking. (p. 246)
*6*—*Calpionellites darderi* (Colom), Neocomian, Ibiza, Balearic Islands. (p. 244)
*7*—*Tintinnopsella longa* (Colom), Barremian, Caravaca, Murcia. (p. 246)
*8*, *10*—*Amphorellina subacuta* Colom, n. sp., Neocomian, Majorca. (p. 250)
*9*—*Rhabdomelloides inesperatta* Colom, Valanginian, Majorca. (p. 249)
*12*—*Coxliellina berriasiensis* Colom, n. sp., Berriasian, Cala Blanca, Majorca. (p. 251)
*14*—*Favelloides pseudoserrata* Colom, Valanginian of Majorca. (p. 249)
*17*—*Tintinnopsella cadischiana* Colom, n. sp., Neocomian of Majorca. (p. 247)
*18*—*Favelloides balearica* Colom, Neocomian of Majorca. (p. 248)
*19*—*Tintinnopsella maxima* Colom, n. sp. Fragment. (p. 247)
*19*—*Tintinnopsella maxima* Colom, n. sp. Fragment. Neocomian, Cape Pinar, Alcudia, Majorca. (p. 247)
*20*—*Salpingellina levantina* Colom, n. sp., Berriasian, Cala Blanca, Majorca. (p. 250)




Colom, Fossil Tintinnid Infusoria




Colom, Fossil Tintinnid Infusoria

probably also in the Hauterivian of the region of the hermitage of La Victoria, Alcudia (Majorca) where the specimens figured in the text were obtained and similar loricas occur in Neocomian beds near Calvia and Andraitx (Majorca).

FAVELLOIDES PSEUDOSERRATA
Colom, 1939
Plate 33, figure 14
Figures 11—*16*

COLOM, 1939, "Las Ciencias" Año 4, no. 4, p. 5' pl. 1, fig. 4; p'. 3, fig. 5.

Lorica conicocylindrical, narrowing gradually towards aboral end which is pointed and probably continued in a caudal prolongation although this does not appear clearly in any section. The oral region is constricted by a wide groove from which the collar opens outward very gently. The few known specimens of this species average about 115$\mu$ in length by 45$\mu$ in width at the center of the lorica.

Similarity in size and general shape may cause this species to be confused with *T. carpathica* but it is easily distinguished by the constricting groove around the oral zone and the collar is never turned as far outwards as in that species. It is, however, very similar to the living species, *Favella serrata*, when they are compared in median sections.

*F. pseudoserrata* is rather rare. I have found only a few specimens in the Valanginian-Hauterivian beds at the hermitage of La Victoria, Alcudia (Majorca) and all of these are not well-preserved.

Genus RHABDONELLOIDES Colom, 1939
Genotype, *Rhabdonelloides inesperatta* Colom

Lorica cylindrical, similar in form to the existing genus *Rhabdonella* (Brandt) Laackmann but notable for the enormous length of its caudal prolongation which is not equalled by any species of the living genus. The relations of these genera may be very close but certain important characters cannot be determined in the fossils. This genus consists of only one species.

RHABDONELLOIDES INESPERATTA
Colom, 1939
Plate 33, figure 9
Figures 11—*9*

COLOM, 1939, "Las Ciencias" Año 4, no. 4, p. 4, pl. 1, fig. 1; pl. 3, fig. 1.

Lorica cylindrical for most of its length but widening somewhat orally and continued aborally by a caudal prolongation nearly twice the length of the lorica. The lorica now consists of minute grains of secondary calcite arranged in rather symmetrical rings suggesting the existence of some kind of circular ornamentation. The figured specimen measures about 130$\mu$ in length without its caudal appendage which is about 200$\mu$ long. The median width is about 41$\mu$.

I have seen only two specimens of this species. One is from the Valanginian marl at the hermitage, Farrutx Mts., Artá (Majorca) and the other from the Neocomian limestone of the island of Cabrera (Balearics). Possibly other sections were not recognized because of improper orientation.

Genus AMPHORELLINA Colom, n. gen.
Genotype, *Amphorellina subacuta* Colom, n. sp.

The new species referred to this genus are similar to species of the existing genus *Amphorellopsis* (fig. 6), but their actual relationships are not certain. None of the

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EXPLANATION OF PLATE 34

(All figures are photographs of thin sections)

FIG. *1*—Fine grained sublithographic limestone from the Valanginian of Majorca formed almost entirely of *Nannoconus colomi*, ×600. (p. 252)

*2*—The same, ×200, showing diminutive spherical corpuscles, transverse sections of *Nannoconus*. (p. 252)

*3*—*Calpionella alpina* and *C. elliptica in* Tithonian limestone from Cape Pinar, Alcudia, Majorca, ×200. (p. 257)

*4*—Radiolaria replaced by iron oxide. Fine grained Neocomian limestones from "Font des Garrove," Mancor, Majorca, ×100. (p. 253)

living species have agglutinated loricas and it is not known whether the fossil forms had agglutinated loricas or not. It seems preferable to propose a new genus rather than to assign Lower Cretaceous specimens to *Amphorellopsis*.

Loricas elongate, slightly ovoid, pointed aborally. Oral collar large, laterally expanded.

AMPHORELLINA SUBACUTA Colom, n. sp.
Plate 33, figures 8, 10
Figures 12—*45, 48, 53, 58–60*

Lorica elongate, conicocylindrical or slightly ovoid, narrowing rapidly from the middle toward aboral end. In some sections the aboral extremity is less pointed than in others and these loricas are somewhat more oval (fig. 12—*53*). Oral opening large with wide out turned collar (fig. 12—*58*). Some specimens have narrower, poorly preserved, or unequally developed collars (fig. 12—*48*).

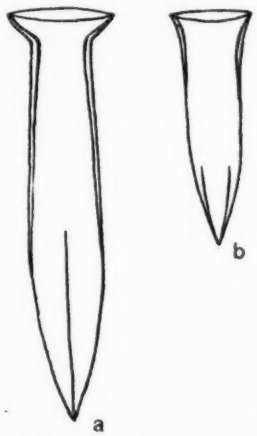



FIG. 6—Living species of *Amphorellopsis*. *a*, *A. acuta* (Schmidt), after Schmidt; *b*, *A. acantharus* Kofoid and Campbell, after Kofoid and Campbell.

The largest loricas of this species are 160$\mu$ in length by 30$\mu$ in width at their centers (fig. 12—*48*). Others are much smaller, 130$\mu$ in length by 30$\mu$ or slightly more in width (fig. 12—*45, 53, 58–60*).

Several of the text figures suggest that more than one species may be represented but I consider the differences too slight for recognition.

This species is not common. It is known only in the basal beds of the Neocomian of Majorca.

AMPHORELLINA LANCEOLATA
Colom, n. sp.
Figures 12—*43, 44, 46*

Lorica conical, narrow and elongate, widest at oral end. The collar is large but not so widely opened as in the former species. Length about 90$\mu$, width 30$\mu$ at the oral opening and thus it is smaller than *A. subacuta*. Figure *46* illustrates a section of a smaller lorica, deformed by pressure whose length (right side) is about 50$\mu$.

This species is not common. It has been found only in the basal beds of the Neocomian of Majorca.

Genus SALPINGELLINA Colom, n. gen.
Genotype, *Salpingellina levantina*
Colom, n. sp.

Loricas of the living genus *Salpingella* Jörgensen are long, narrow, cylindrical and trumpet-shaped, and generally have funnel-like collars. These characters are also possessed by some fossil forms but it is not possible to determine whether they are closely related to the living species.

SALPINGELLINA LEVANTINA
Colom, n. sp.
Plate 33, figure 20
Figures 13—*58, 60, 61*

Loricas very elongate, narrow, conicocylindrical; aboral end more or less pointed perhaps because of variable orientation but possibly more than one species is represented. Many specimens have poorly-preserved oral openings (see figures 13—*58, 61*) but in others they are perfectly preserved, with a widely opened funnel-shaped collar (fig. 13—*60*). Loricas of both types are included under one name as it is not certain that they can be distinguished.

This is a scarce but not rare, species. It is widely distributed from Cala Blanca to Cape Pinar in Majorca in Valanginian-Hauterivian limestones and it has also been found by Professor B. Darder in the limestones at Bañeres (province of Alicante, Spain).

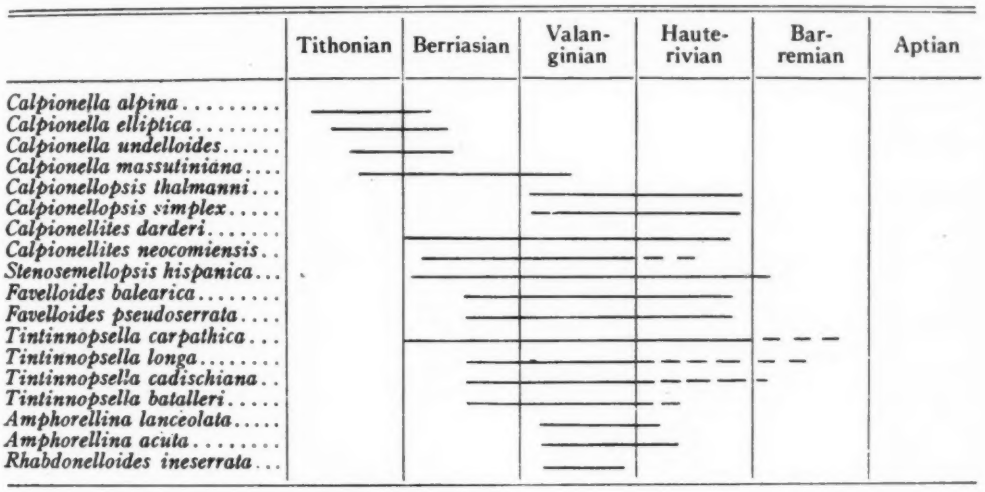
Genus COXLIELLINA Colom, n. gen.
Genotype, *Coxliellina berriasiensis* Colom, n. sp.

The existing genus *Coxliella* (Brandt) Lachman includes species with very elongate cylindrical tests, with or without caudal appendages. The lorica is composed of a helical band of varying width whose walls are double with a clearly visible intermediate lamina. In the following fossils such structures cannot be determined but their general shapes suggest such species of *Coxliella* as *C. helix* Claparède and Lachman, a large form that reaches a length of 150$\mu$ and has much agglutinated material, especially in its aboral region.

## DISTRIBUTION AND ENVIRONMENT OF FOSSIL TINTINNIDS

In Majorca, tintinnids first appear in Tithonian strata as many observations show that they also do in other parts of the Tethys regions. They invariably occur in deep-water sediments that can be correlated on the basis of cephalopods. Three species are present in enormous numbers, *Calpionella alpina* Lor., *C. elliptica* Cadisch and *Tintinnopsella carpathica* (Murgeanu and Filipescu), and obviously constituted an important part of the plankton in the Tithonian and Neocomian seas in whose sediments they are widely distributed. Other species are nowhere so abundant al-

TABLE 1




though some of them are more or less common in certain zones where they lend variety to the fauna.

The tintinnids first appear in fine grained limestones that alternate with the "faussesbrèches" of the Tithonian and some have been found in the latter strata but this occurrence is exceptional. The "faussesbrèches" are fine grained sediments composed largely of organic detritus in which Radiolaria are preserved as calcite moulds. The matrix consists of exceedingly fine grained calcite formed in part by enormous quantities of coccoliths, visible through the

COXLIELLINA BERRIASIENSIS
Colom, n. sp.
Plate 33, figure 12
Figures 13—62

Lorica elongate, cylindrical, widest aborally and narrowing gradually toward mouth. There are no traces of an aboral appendage and this end appears in section as a somewhat flattened curve. Also there are no signs of an oral collar and at this extremity the walls end simply. The single specimen from limestone of Berriasian age at Cala Blanca (Majorca) reaches a length of approximate 200$\mu$.

microscope on the thinner edges of the slides. As they consolidated, these sediments were profoundly disturbed by submarine currents which produced their pseudo-brecciated structure.

*Calpionella alpina* and *C. elliptica* appear abruptly in some strata of the lower Tithonian of Majorca alternating with other beds which have no trace of these fossils. Higher in the Tithonian the sediments are some-

FIG. 7—*Nannoconus colomi* (de Lapparent). Longitudinal and transverse sections, ×300. Neocomian of Majorca.

what different and fine grained very pure limestone predominates. Some beds carry *Globigerina* but others contain the extremely abundant remains of strange organisms which characterize the upper Tithonian, Neocomian and Barremian strata to the base of the marly facies of the Aptian-Albian. These are known as *Nannoconus colomi* (de Lapparent) and occur in such immense numbers that they constitute the greater part of the rock.

The Lower Cretaceous of Majorca consists of fine, sublithographic limestone with occasional intercalcations of more or less marly beds. They are all light in color, grayish-white or greenish-gray, and of very uniform composition. They are sediments of pelagic origin, free from terrigenous additions. The remains of a rich plankton is preserved in them, consisting of coccoliths in abundance, Radiolaria and tintinnids. *Nannoconus* is present in them all. This fossil is an enigmatic form and it is not known whether it was a member of the plankton or of the benthos. Its discoverer believed it to be a diminutive species of *Lagena* (foraminifer) (fig. 7, text) but shortly after the publication of Professor de Lapparent's studies, Professor Kamptner of Vienna, who was in ignorance of them, described this fossil under the name of *Nannoconus steinmanni*. Its taxonomic position is not clear. Dr. Cadisch recently wrote me that he believes it to be a unicellular, chlorophyllaceous alga which produced a calcareous test. The reader interested in the affinities and taxonomy of this species is referred to the original papers of de Lapparent (1925a, b, 1931) and Kamptner (1931, 1938) and to a recent note of mine dealing with these subjects (1945).

The Lower Cretaceous limestones dissolve in acids with intense effervescence and leave hardly any residue except for some layers which are more or less argillaceous. As observed through the microscope, attack by hydrochloric acid seems to reveal a slight siliceous impregnation best developed near the radiolarian moulds. This silica, which is largely organic, accounts for the siliceous replacement of the few tests of Foraminifera occurring in these sediments. These rocks contain few other minerals or remains of organisms such as fragments of ammonites, rare echinoid plates, etc. Among the primary minerals are small isotropic grains of yellowish calcium phosphate, probably fragments of bone, which are more or less abundant in certain zones at some localities. Only a few emerald-green granules of glau-

EXPLANATION OF PLATE 35

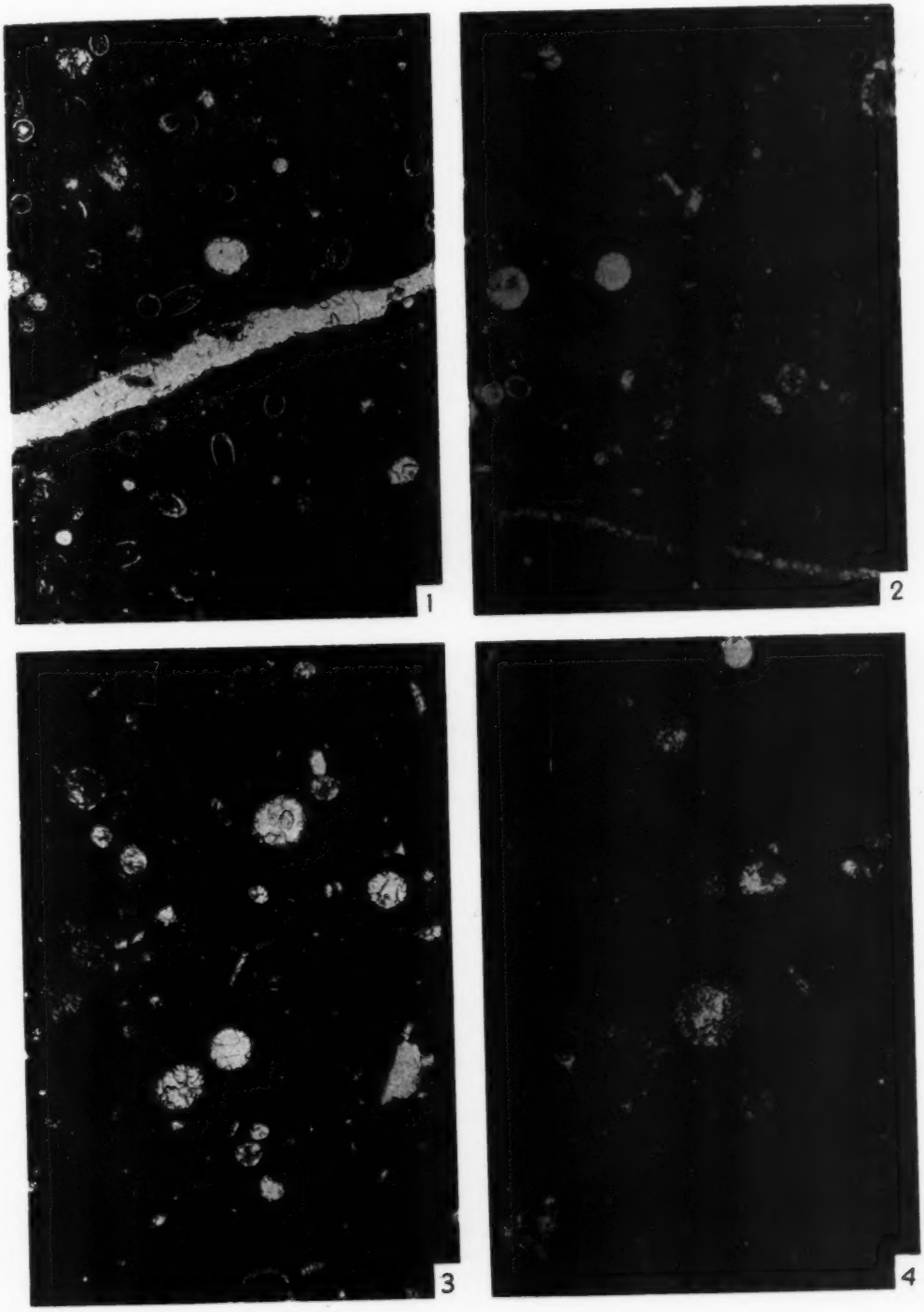
(All figures are photographs of thin sections.)

FIG. 1—*Tintinnopsella carpathica* in Hauterivian limestone from Cala Blanca, Andraitx, Majorca, ×200. (p. 245)

2—*Calpionella alpina* in Tithonian limestone from the Farrutx Mountains, Artá, Majorca, ×200. (p. 257)

3—Molds of Radiolaria filled with calcite. Neocomian limestone, Majorca, ×150. (p. 253)

4—Radiolaria replaced by calcite. Portions of the long radial spines can be observed. Hauterivian-Barremian marly limestone, Cala Blanca, Andraitx, Majorca, ×250. (p. 253)




Colom, Fossil Tintinnid Infusoria

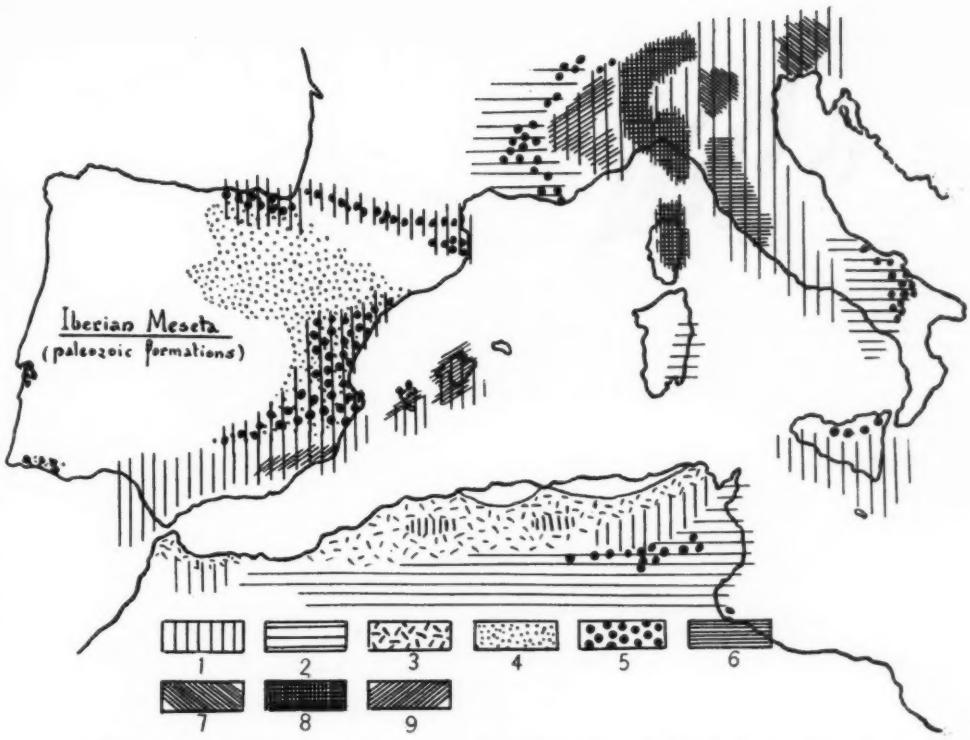



FIG. 8—Paleogeography of the western Mediterranean in Barremian-Aptian time.
1—Deep sea facies.
2—Neritic facies.
3—North Africa zone of "Flysch" facies.
4—Wealdian continental facies.
5—Organic and detrital limestones with rudistids and *Orbitolina* formed on the borders of deep zones.
6—Facies of fine sublithographic "majolica" limestones of Italy, with *Nannoconus*, Radiolaria, and abyssal pelagic sediments.
7—"Biancone" facies, of similar composition.
8—"Schistes lustrés" of the Alps and Corsica; abyssal metamorphic facies.
9—Sublithographic limestones with *Nannoconus*, Radiolaria and tintinnids; abyssal sediments of Spain and France (Provence), similar in composition to the "biancone" and "majolica" limestones of Italy.

conite occur, probably derived from a distant coast. Terrigenous minerals include diminutive quartz grains, always scarce and entirely lacking in many beds, and a few flakes of biotite and rare rutile crystals.

Among the pelagic organisms Radiolaria are very abundant and are represented by planktonic genera with globular, discoidal or conic tests, some with long spines. They are all completely replaced by calcite, except for a very few which now consist of iron oxide (Plate 34, figs. 3, 4). These altered tests are generally very poorly preserved.

Coccoliths, *Coccolithes*, *Pontosphaera*, etc., are also very abundant and their enormous numbers indicate that these deposits accumulated in warm, tropical waters. All are broken and I have seen no complete specimens.

Foraminifera are almost completely absent from this pelagic facies although a few sections of rotalids etc. do occur. *Globigerina* is very rare and has been found only in the higher strata of the Neocomian deposits in the central part of the island. Some tests preserve their original structures but others

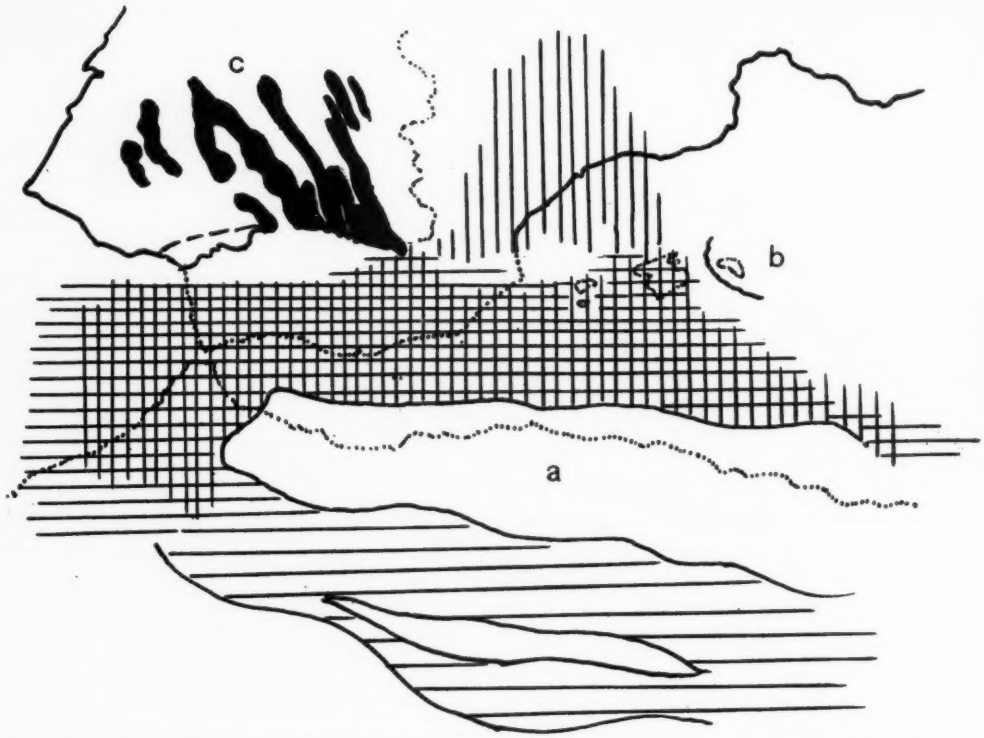



FIG. 9—Paleogeography and distribution of "fausse-brèches" facies in the western Mediterranean during the Lusitanian stage. (From Failot, Bull. Soc. Geol. France, 1932).
Vertical lines—neritic facies.
Squares—dominion of the Upper Jurassic "fausses brèches". Earliest tintinnids.
Horizontal lines—Lusitanian transgressions in North Africa.
*a*—Emergent zone, Upper Jurassic lacking
*b*—Zone of Island of Menorca, Upper Jurassic lacking.
*c*—Emergent Iberian meseta.

have been completely replaced by silica. The almost complete absence of *Globigerina* and other calcareous forms from the marly-limestones is very strange. Such tests may have been destroyed by recrystallization or in thin sections single chambers may have been mistaken for radiolarian moulds. Possibly, as happens in existing oceans, the tests were partially dissolved and reduced to calcareous mud at the bottom of the Cretaceous sea.

Upper Tithonian and younger sediments of Majorca, especially the Valanginian, Hauterivian and Barremian, exhibit abyssal characters and are lithologically uniform throughout a large area. Only in the eastern part of the island, in the Farrutx Mountains of Artá and at a few other nearby localities, a distant coast and emergent land which existed in the neighborhood of what is now the island of Menorca, left slight traces of neritic influences in the Valanginian-Hauterivian strata. The abyssal sediments carry a rich ammonite fauna (*Phylloceras*, etc.) which includes practically no remains of coastal organisms. The Barremian sediments of Majorca are most uniform lithologically and this stage marks the maximum extension of such deposits, which occur even in the eastern part of the island (Artá). The physical conditions that prevailed in the surface waters of the upper Tithonian and

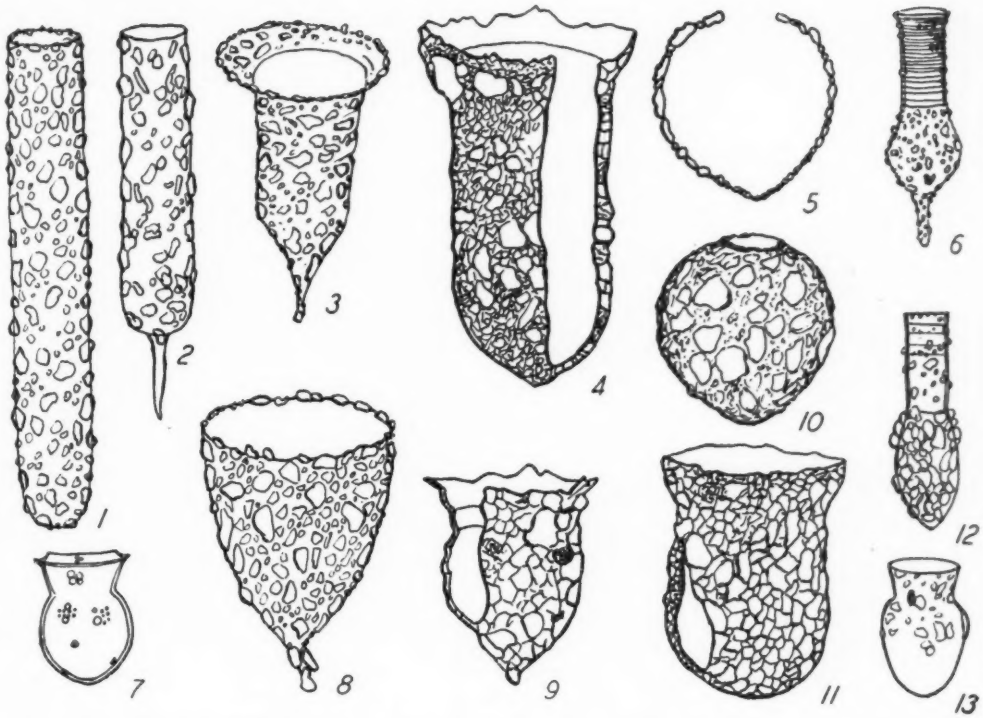



FIG. 10—Living species of tintinnids. *1, Tintinnopsis lobiancoi* Daday, Bay of Naples; *2, T. platensi* Cunha and Fonseca, South Atlantic; *3, T. campanula* (Ehrenberg) Daday, Bay of Naples; *4, T. loricata* Brandt, Sea of Borneo; *5, 10, Stenosemella ventricosa* (Claparéde and Lachman), after Deflandre; *6, Codonellopsis longa* Kofoid and Campbell; *7, Codonella cistellula* (Fol.) Brandt, (after Jörgensen); *8, Tintinnopsis vosmayeri* Daday (after Daday), Bay of Naples; *9, T. balthica* (Claparède and Lachman) (after Brandt), Bay of Kiel; *11, T. orientalis* Kofoid and Campbell (after Brandt), Coast of Peru; *12, Codonellopsis lusitanica* Jörgensen (after Jörgensen); *13, Codonella galea* Hck. (after Jorgensen. All figures ×250.

Lower Cretaceous seas are unknown but they must have been extraordinarily favorable for tintinnids and the immense profusion of these infusoria indicates stable conditions that endured with great uniformity throughout the entire Balearic area for a long period of geological time.

In my investigation of the biostratigraphy of the tintinnids, I have studied with particular attention the stratigraphic series that extends from the Upper Lias to the Barremian at Cape Pinar (Alcudia, Majorca) and the even more complete series at Cala Blanca (Andraitx Majorca) as well as the deposits at Son Muntaner, Santa Eulalia etc. near Palma, which are well-known for their rich ammonite faunas. Altogether they constitute a magnificent stratigraphic succession. The majority of these strata are fossiliferous and they are the classic deposits for a study of the Lower Cretaceous in Majorca.

In the deposits of Cape Pinar, tintinnids are not known to occur below the Tithonian limestone which follow the "faussesbrèches." These pinkish or greenish sediments contain numerous moulds of Radiolaria. Their presence therein is normal as Radiolaria abound throughout the whole series of sediments from the Upper Lias on. Tintinnids and *Nannoconus*, however, have been found nowhere in strata older than the

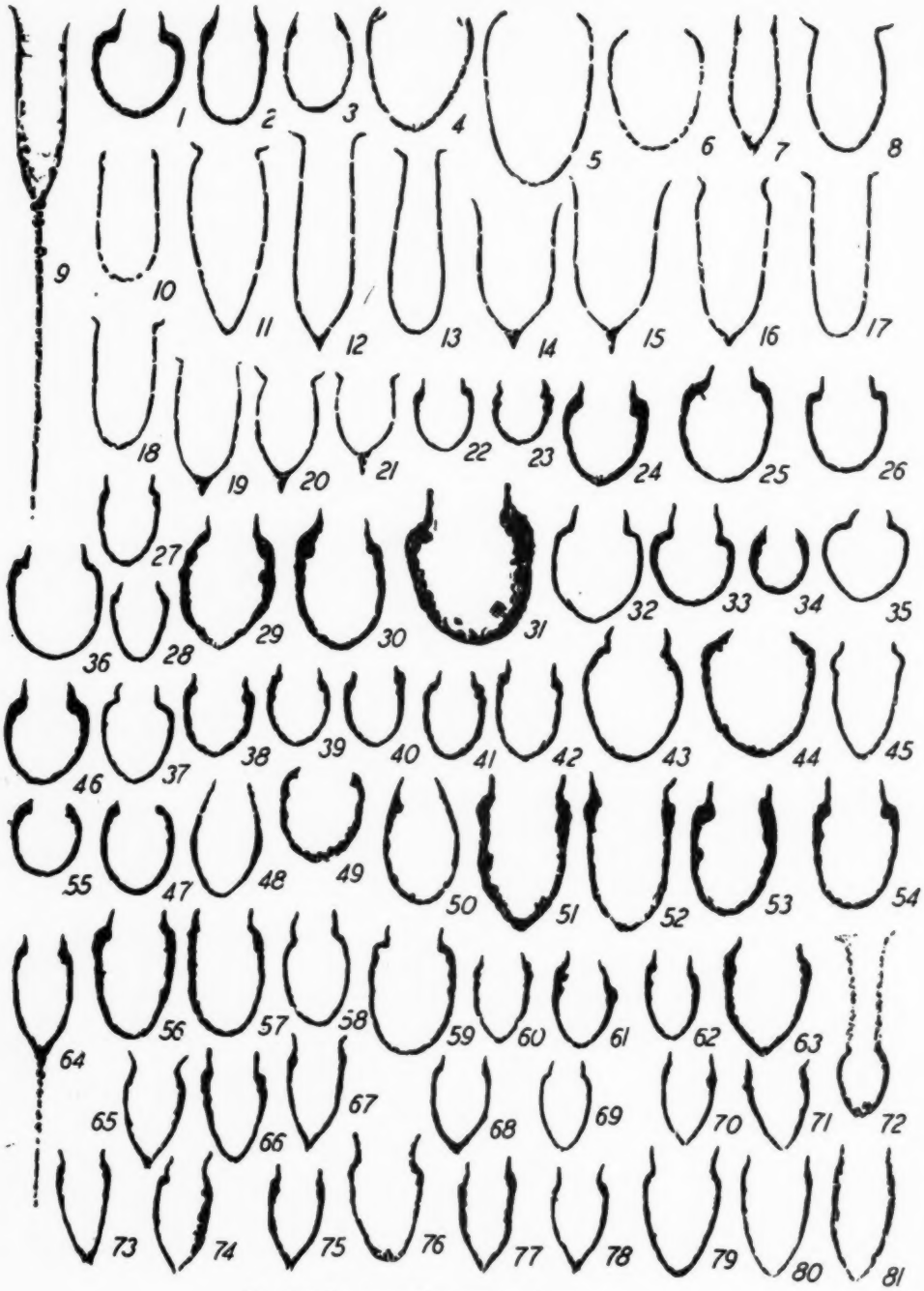



FIG. 11. See opposite page for description.

Tithonian. The first tintinnids appear suddenly and loricas of *C. alpina* and *C. elliptica*, together with a few others that I have not been able to determine, are rather common at Cape Pinar in the hard, fine-grained limestones overlying the "fausses-brèches."

The first specimens clearly related to *T. carpathica*, and also a few representatives of *C. undelloides*, occur in higher strata referable to the Berriasian. Locally some strata carry abundant Radiolaria but in these tintinnids are almost wholly absent. This alternation of strata with Radiolaria and others with tintinnids is common and has also been observed in the Carpathians by Andrussof and Koutek. In higher Tithonian beds, *C. alpina*, *C. elliptica*, *C. undelloides* and *S. hispanica* occur together. Enormous numbers of *C. alpina* are present in some zones (Plate 34, fig. 3, Plate 35, fig. 2). In upper Berriasian strata *T. carpathica* occurs in increasing abundance, accompanied by *S. hispanica*, numerous specimens of *C. elliptica* and also *C. massutiniana*. Where *C. elliptica* predominates, *C. alpina* is largely absent, although elsewhere it occurs locally in great numbers.

Many specimens of *C. darderi* and *S. hispanica*, the latter species represented both by its typical form and its variety, are present at Cape Pinar, in Valanginian beds and continue into the Hauterivian. Loricas of the group of *T. longa* are rather abundant also and some specimens occur in the Hauterivian but in beds which carry Barremian ammonites this species becomes quite rare.

At Cala Blanca (Andraitx) the distribution is similar. *C. alpina* and *C. elliptica* occur at the base, in beds overlying the "fausses-brèches." *T. carpathica* appears in increasing abundance in upper Tithonian zones and younger strata where it is accompanied by *F. balearica*, *C. simplex*, *S. hispanica* and some unidentified forms. In successive beds of undoubted Berriasian age the following occur:

*S. hispanica*, *C. neocomienses*, *T. carpathica* and other unidentified forms (Slide 13).

The same and also *T. longa* and a few specimens of *C. elliptica* (Slide 14).

*T. longa* and many doubtful specimens of *C. simplex* (Slide 15).

*S. hispanica; C. elliptica* and *C. neocomiensis* (both rare); *T. carpathica* (Slide 16).

Possibly the last assemblage is of Valanginian age. Tintinnids become scarcer in overlying strata to the top of the Barremian where the partly marly limestones give place to entirely marly beds with pyritic ammonites. Many of the marly-limestone strata, however, contain tintinnids, mostly large specimens of *T. carpathica*, *T. longa* and *T. cadischiana*. I have found the first two species to continue in greater or less numbers up to beds of Barremian age.

In other parts of Majorca the same dis-

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FIG. 11—*1 Calpionella alpina* Lorenz, Tithonian of Majorca; *2, 51–81, C. elliptica* Cadisch, Tithonian of Majorca, *51–54, 56*, are large typical loricas, *57–60, 63*, are of medium size, *64*, a lorica with long caudal appendage, *61, 62, 65–71, 73–81* with pointed aboral end, and *72*, a lorica with a cylindrical neck continuing the oral collar. The last is from the Tithonian at Cala Blanca, Andraitx, Majorca. *3. C. undelloides* Colom, Tithonian of Majorca; *Calpionellites darderi* (Colom) Neocomian, Cape Pinar, Majorca; *5, 6, Stenosemellopsis hispanica* (Colom), Neocomian, Cape Pinar, Majorca; *7, Calpionellopsis thalmanni* (Colom), Valanginian, Artà, Majorca; *8, Tintinnopsella carpathica* (Murgeanu and Filipescu), Valanginian, Artà, Majorca; *9, Rhabdonelloides inesperatta* Colom, Valanginian marls, Majorca; *10, Calpionellopsis simplex* (Colom), Neocomian, Puigpunyent, Majorca; *11, Tintinnopsella doliphormis* (Colom), Neocomian, Artà, Majorca; *12, 17, T. longa* (Colom), *12*, Neocomian of Artà, *17*, Barremian, Cala Blanca, Andraitx; *13*, T. oblonga (Cadisch), Valanginian, Majorca; *14, 15, Favelloides balearica* Colom, Neocomian, Alcudia, Majorca; *16, F. pseudoserrata* Colom, Neocomian, Alcudia, Majorca; *18–21 Tintinnopsella carpathica* (Murgeanu and Filipescu), Neocomian, Majorca; *22–33, 35–43, Calpionella alpina* Lorenz, Tithonian of Majorca, *22, 23, 28, 38, 39* are diminutive, the rest are the normal form; *34, 47, 49, 55, C. undelloides* Colom, Tithonian of Majorca; *44, C.* cf. *alpina* Lorenz, Tithonian of Majorca; *45, C. massutiniana* Colom n. sp., Tithonian of Majorca; *48, 50, C. elliptica* (?) Cadisch (abnormal loricas), Tithonian of Majorca;. All figures ×250.

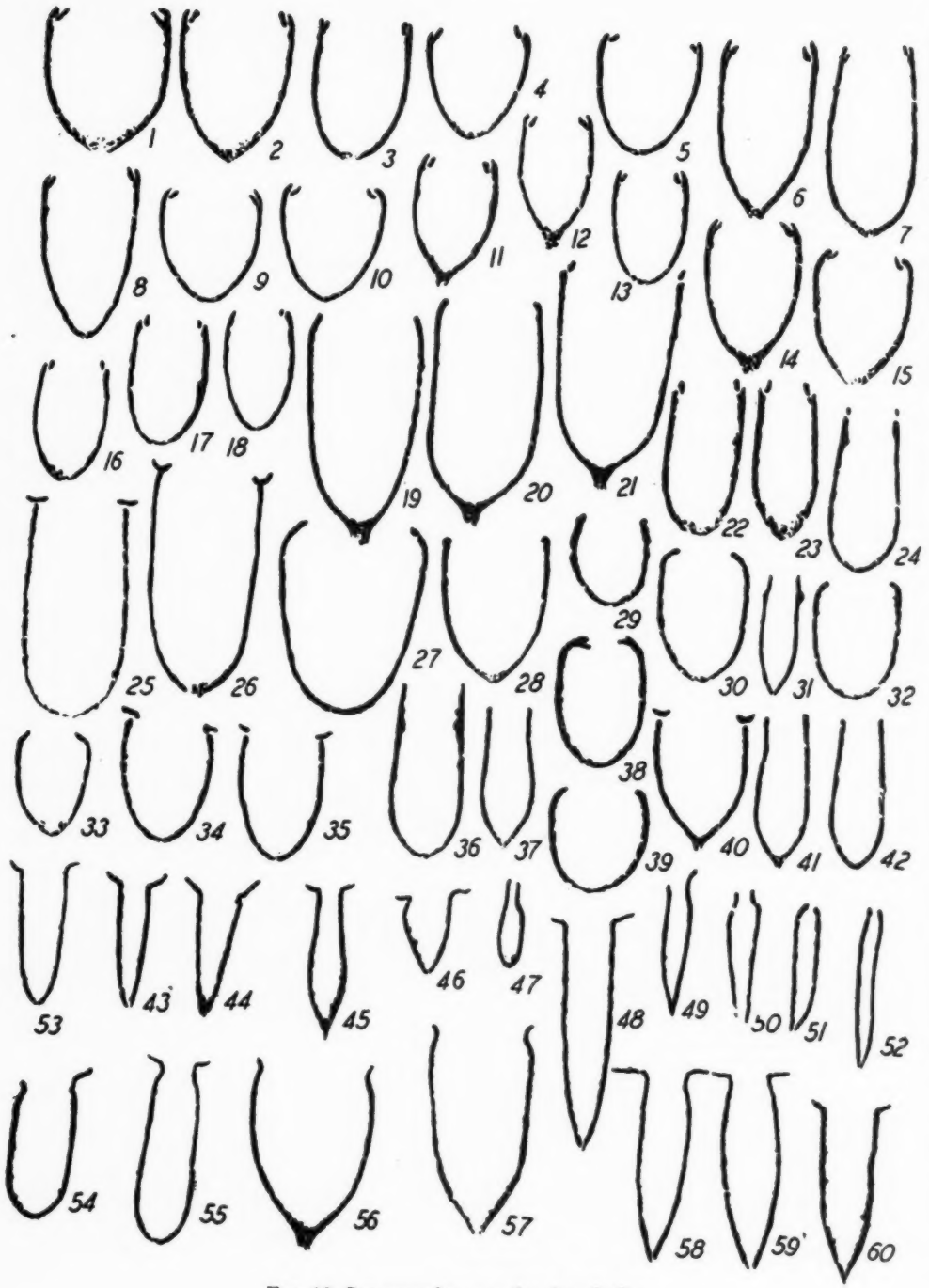


FIG. 12. See opposite page for description.

tribution occurs. Such species as C. *darderi*, *S. hispanica*, *T. batalleri* and especially the large loricas of *T. longa* are present in Neocomian strata. I have also found numerous specimens of the large forms of *T. carpathica* and *T. longa* in samples from Caravaca (province of Murcia, Spain) that Professor Bataller identifies as Barremian.

*T. carpathica*, as recognized here, possesses the greatest vertical distribution, occurring from the Berriasian to the Barremian. It may be possible eventually to distinguish varieties of this species characteristic of different stratigraphic zones. Its presence without *C. alpina* or *C. elliptica* indicates Neocomian strata. Large numbers of *C. alpina* and *C. elliptica*, however, characterize the Tithonian, or if the latter species only is abundant, Berriasian beds.

Species described in this paper, but not mentioned in the foregoing discussion, are rare and unimportant stratigraphically. The occurrence of each has been noted and further observations in other regions may show some of them to be restricted.

The Lower Cretaceous series in the island of Ibiza is similar to that in Majorca. Also the Neocomian and Barremian deposits of southeastern Spain, as developed near Caravaca (province of Murcia), Cocentaina, Jesus Pobre, Bañeres (province of Alicante), are identical with those of the Balearic Islands.

In recent years numerous authors have mentioned the occurrence of Calpionellae in other countries but I shall note only those works in which they are given special attention or identified. Murgeanu and Filipescu reported them in 1933 and 1938 from various localities in Roumania. Professor Andrussof in an interesting paper on the vertical distribution of microorganisms in the Mesozoic sediments of the Eastern Carpathians published in 1931 commented on the distribution of the Calpionellae in that region. Professor Jodot (1931–1938) in various reports on the sedimentary rocks of Corsica mentioned their occurrence in the upper Jurassic beds of that island.

The French geologist Laffitte (1937) has studied in detail the distribution of the Calpionellae in North Africa (Algiers) and found that *C. alpina* and *C. elliptica* abound in Portlandian or Berriasian strata but that *T. carpathica* first appears in the uppermost beds of the latter stage. He reported, however, that he found no specimens in any younger rocks. I have no direct knowledge concerning the vertical distribution of tintinnids in North Africa, but the similarity of the Cretaceous deposits there and in Majorca leads me to predict that new investigations will result in their discovery.

More recently Blumenthal noted the occurrence of Calpionellae in gray or somewhat greenish limestones at Villa Jordana (zone of Bokoya, Spanish Morocco). According to Professor Cadisch (1932) the species present there is *C. elliptica*. Blumenthal, however, believed the beds to be Oligocene and intimately related to others containing *Lepidocyclina*. I suspect that structural complications in this part of the Riff have obscured the stratigraphic sequence because it would be most surprising for so typical a Tithonian or Berriasian species to reappear in beds of Oligocene age.

The interesting lithological facies characterized by coccoliths, Radiolaria, tintinnids and *Nannoconus colomi* has been carefully studied only in the Balearic Islands (Colom 1928–1935) but it seems to be well represented throughout the Alpine region, wherever more or less abyssal sediments uncon-

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FIG. 12—*1–15 Calpionellites darderi* (Colom), Neocomian of Cape Pinar, Alcudia, Majorca; *16–18, 22–24, C. neocomiensis* Colom n. sp., same locality and formation as the preceding; *19–21, 25, 26, 34, 35, 40, Tintinnopsella cadischiana* Colom n. sp., Neocomian of Majorca; *27–30, 32, 33, 37, 39, Stenosemellopsis hispanica* (Colom), Neocomian, Majorca; *31, Calpionella sp.*, Tithonian, Majorca; *36, C.* cf. *thalmanni* (Colom), Tithonian, Majorca; *38, 41, 42, C.* sp., Tithonian, Majorca; *43, 44, 46, Amphorellina lanceolata* Colom n. sp., Neocomian, Majorca; *47, 49–52*, tintinnids (?) Tithonian-Valanginian, Cala Blanca, Andraitx, Majorca; *45, 48, 53, 58–60, Amphorellina subacuta* Colom n. sp., Neocomian, Majorca; *54, 55, Tintinnopsella batalleri* Colom n. sp., Neocomian, Majorca; *56,. Favelloides balearica* Colom, Neocomian, Majorca; *57, F. pseudoserrata* Colom, Neocomian, Majorca All figures ×250.

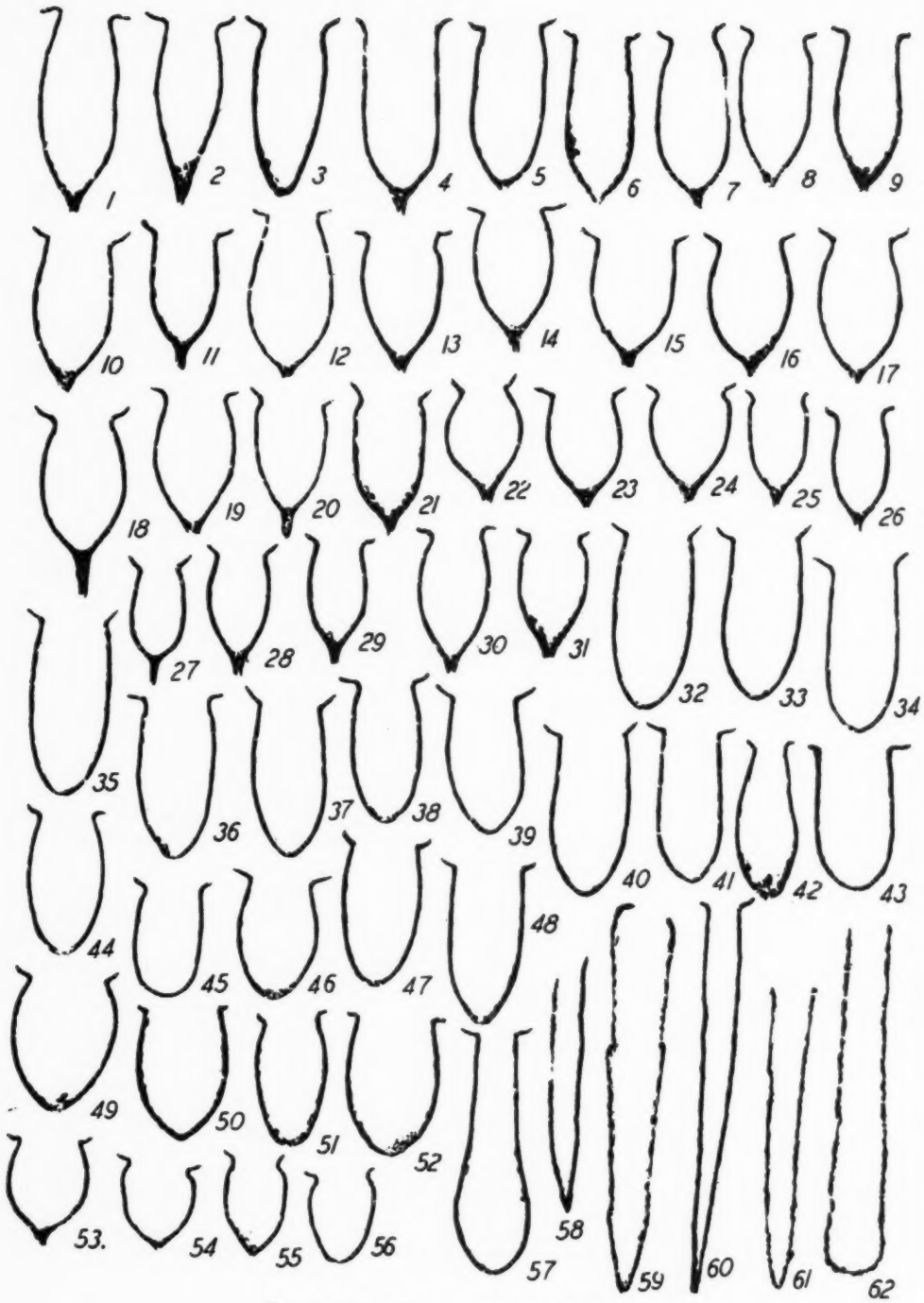


FIG. 13. See opposite page for description.

taminated by terrigenous material accumulated. The wide extent of this facies throughout the zone of subsidence of the Mesozoic Mediterranean Tethys is slowly being confirmed. Only fragmentary records are now available but from the Caravaca deposits in the province of Murcia (Spain) this facies seems to extend through the Balearics and the region of Berrias in Provence (France) to the fine grained limestones with tintinnids and *Nannoconus* in Italy, where Professor J. de Lapparent (1935) found beds of the Biancone formation of Chiasso and Camago, near Como, to be similar to those of France and Spain. The Biancone limestone of Val Breggia contains *Nannoconus* associated in certain strata with numerous Calpionellae and Dr. Cadisch reported the presence of these same fossils in the Swiss Alps in 1934.

The limestones termed "majolica" in Italy are similar in composition and contain moulds of Radiolaria and numerous Calpionellae. Professor Steinmann believed "majolica" to have been lime mud deposited at a depth of 3000 or 4000 meters made up of a mass of microfossils which he erroneously identified as coccoliths because he mistook the transverse sections of *Nannoconus* for the simple discs of unicellular algae. The studies of Kamptner, however, have shown that the "pseudococcoliths" of Steinmann are the same as the microfossils which he described as *Nannoconus steinmanni* and which Professor Cadisch earlier identified as *Lagena colomi* de Lapp. These observations show that the white "majolica" limestone of Biancone, which carries *Nannoconus*, Radiolaria, and locally tintinnids, is almost identical to the Balearic limestones in age and lithology.

Some years ago Professor Dervieux of the University of Milan examined at my request many thin sections of fine grained Italian limestones because of my interest in the discovery of *Nannoconus* there (1931). These rocks proved to be shallow water deposits with neritic fossils but I consider Kamptner's study important because it confirmed the presence of this peculiar facies in the Lower Cretaceous at Monte Pavione.

In the Roumanian Carpathians, a similar limestone facies has been found in the Bar-

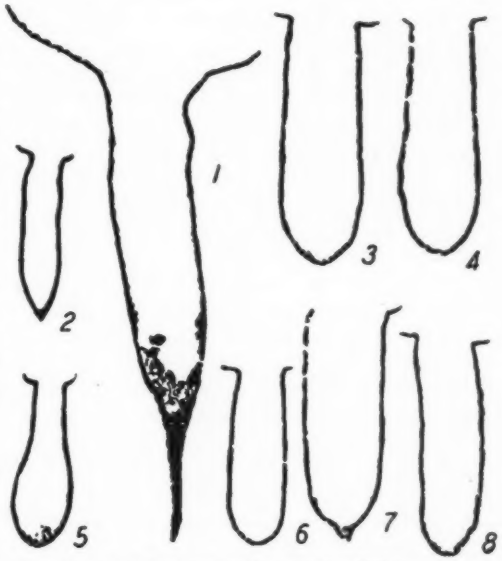


FIG. 14—*1, Tintinnopsella maxima* Colom, n. sp., Neocomian, Cape Pinar, Alcudia, Majorca; *2–4, 6–8, T. longa* Colom, Neocomian, Majorca; *5, T. oblonga* (Cadisch), Tithonian and Valanginian Majorca. All figures ×250.

remian of Plaine Sirnelor by my friend, G. Murgeanu (1931) but the beds here are not so pure and seem to reflect near-shore influences.

Probably future studies will provide additional information concerning the distribution throughout the Alpine region of these formations with a pelagic open sea association of coccoliths, Radiolaria, tintinnids

FIG. 13—*1–31, Tintinnopsella carpathica* (Murgeanu and Filipescu), loricas of various sizes, showing the existence of a caudal appendage, Tithonian and Neocomian of Majorca; *32–56*, same species, loricas without a caudal appendage, but *53–56* displaying traces of the structure; *57, Tintinnopsella oblonga* (Cadisch), Tithonian and Valanginian, Majorca; *58, 60, 61, Salpingellina levantina* Colom, n. sp., Barremian, La Foya Redona, Bañeres, Alicante; *59*, tintinnid (?), Valanginian, Cape Pinar, Alcudia, Majorca; *62, Coxliellina berriasiensis* Colom, n. sp., Cala Blanca, Andraitx, Majorca. All figures ×250.

and *Nannoconus* preserved in abyssal deposits which are purer the farther they were removed from terrigenous influences. The extensive deposition of the so-called "couches-rouges" with *Rosalina* throughout the entire Mesogea during the late Cretaceous suggests that this earlier facies, with its equally typical microorganisms, will be found to occupy a comparable region.

Future studies may also extend the known distribution of the tintinnids in both time and space. They were first noted at only a few localities in the Alps but other occurrences were discovered throughout the Mediterranean depression and as far eastward as Crimea and the Caucasus (Vassoevitch 1936). I do not agree with Professor Jodot who wrote, concerning sedimentary rocks of Corsica (1933a), "Je crois pouvoir déduire que le genre *Calpionelle* parait avoir survécu plus longtemps dans le mesozoique du bassin méditerranéen *sensu latu* que dans les régions alpines occidentales." Certainly many facts remain to be learned regarding the history of the tintinnids and such a statement seems premature.

Some geologists have doubted the existence of tintinnids in Barremian beds because of the general belief that they are characteristic only of the Tithonian and possibly of the Berriasian. The two species *C. alpina* and *C. elliptica* are so restricted but generalization is not warranted and other species have been discovered in the abyssal deposits of the Lower Cretaceous in Majorca, Ibiza and southeastern Spain. The persistence of these planktonic infusoria during a great part of the Lower Cretaceous, at least in Majorca, is not surprising in view of the monotony of the marly limestones of that age which clearly reveal the continuation of very stable physical conditions. These peculiar conditions clearly favored the abundant existence and development not only of tintinnids but also of the other microorganisms that have been mentioned and a similar association may not be found elsewhere in the Mediterranean region.

There is no doubt, however, regarding the existence of tintinnids in the Barremian beds of Majorca as they have been found in certainly identified deposits of that age. They continued to be an important part of the plankton and were preserved in the fine grained sediments of the Lower Cretaceous now exposed in the Balearics as long as favorable conditions persisted.

Tintinnids and *Nannoconus* disappear suddenly at the end of the Barremian in Majorca. Their disappearance coincides with a change in the sediments which reflects the different physical and paleogeographical conditions of the Aptian. These deposits in Majorca are argillaceous and abundant detrital material indicates an important shoaling of the sea. The change grows more marked upward in the Aptian and the strata are such that preservation of frail tintinnid loricas was impossible. I am confident that no tintinnids will be found in the Aptian-Albian of Majorca.

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# PALEONTOLOGIST—BIOLOGIST OR GEOLOGIST?

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THE PROVOCATIVE and controversial subject chosen by J. B. Knight for his presidential address before the Paleontological Society of America[1] has stimulated general discussion and comment enjoyed by few such addresses in the history of the Society, and has resulted in at least two public replies to date, one, by Raymond C. Moore, likewise a presidential address before the Paleontological Society[2] in which carefully qualified approval is indicated, and the other, a vigorously disapproving paper by J. Marvin Weller.[3] While not subscribing to all of Knight's conclusions we nevertheless believe that he has done a real service to paleontology and geology in calling attention to serious traditional deficiencies in the training of invertebrate paleontologists. Some of these deficiencies are clearly recognized by Weller. As Knight shows, they are the product of the historical affiliation and subservience of invertebrate paleontology to nonbiological geology, a conclusion with which Weller apparently does not agree. It appears to us that Moore and Weller do not recognize the problem as clearly as does Knight, and there is a tendency for them to lose sight of the very real problem in their enthusiastic rejection of some of Knight's remedies.

Knight concludes that paleontology, although intimately related to both geology and biology, is sufficiently distinct in objectives and methods to be classed as a separate science. He believes that the organization of paleontology departments in the universities, apart from the geology departments, would be beneficial to both paleontology and geology.

It is not likely that many universities could be persuaded to erect separate paleontology departments, although this has been done in at least one instance, because of the excessive administrational costs involved. In any case a debate over Knight's proposal is a somewhat sterile activity, in our opinion, since paleontology in the broadest sense certainly shares equally in the subject matter usually offered by departments of biology and geology. In a more limited way paleontology can be almost wholly one or the other, but such restriction applies to only limited branches of paleontology, and not to the entire field.

Professor Weller's point of view admirably expresses the traditional attitude of the geologist toward paleontology. This is an attitude which Knight believes, and we heartily agree with him, should be changed for the best interests of geology, as well as paleontology. Our remarks are not intended to reflect other than the deepest admiration for Professor Weller, who is among the vanguard of the most progressive stratigraphic geologists. We emphatically disagree with him, however, in what we regard as a narrow view of paleontology. This philosophy, because it is widespread amongst geologists, is being modified only too gradually.

The manner in which paleontology can be almost wholly incorporated within one or the other of the sciences of geology or biology is well illustrated by Professor Weller, where he states that "I think of myself as a geologist first and as a paleontologist second and I consider paleontology to be a branch of geology. . . . " (Op. cit., p. 570.) This is a most revealing remark, and perhaps it illustrates why invertebrate paleontology, in particular, is so closely bound, and one might say, is subservient, to stratigraphic geology. Using this as a basis for his thesis, he categorically defines the limits and relationships of paleontology. For instance, "In my opinion, invertebrate paleontology is much more closely related to geology than to biology." And farther on, "paleontology without geology is biology and nothing more." (Op.

[1] Knight, J. B., Paleontologist or geologist, Geol. Soc. Am., Bull., Vol. 58, pp 281–286,1947.
[2] Moore, Raymond C., Stratigraphical paleontology, Geol. Soc. Am., Bull., Vol. 59, in press, 1948.
[3] Weller, J. Marvin, Relations of the invertebrate paleontologist to geology, Jour. Paleontology, Vol. 21, pp. 570–575, 1947.

cit., p. 572.) If paleontology is at the present largely a branch of geology, and is in many cases a secondary supporting technique for stratigraphy, it is because paleontologists, through lack of adequate training in biology, have made it so.

None of the three discussants has clearly or adequately analyzed paleontology itself. We hold that paleontology is the *study of fossils*, for whatever objectives or reasons. General objectives suggest a two-fold division into paleobiology, which is basic paleontology, and stratigraphic paleontology, which is really applied paleontology. Paleobiology is, of course, mainly biological in objectives, but many of its techniques are unknown to biology. For instance, its methods in the field are partly those of stratigraphy. Stratigraphic paleontology on the other hand is clearly geological in its objectives, yet even so its methods and philosophies are in part more closely allied with biology than with geology. This is to say that it is more akin to some fields of biology than, for example, to mineralogy or geophysics.

So we see that even in this division of the subject into paleobiology and stratigraphic paleontology no hard and fast lines can be drawn to make the dichotomy complete. Paleobiology is related to geology as well as to biology, while stratigraphic paleontology has many biologic aspects in addition to its geological functions. All of this affords one more illustration of the fact that borderline and intermediate subjects are numerous in the large field of geology. Thus, geophysics and geochemistry link geology with the physical sciences, yet to claim that these are exclusively geological sciences simply because they are devoted to earth problems is as untrue as to class chemistry and physics as geological sciences in those areas where they deal with elements and atoms, earthly substances.

Professor Weller asserts that paleontology in its broadest sense is exclusively a field of geological science. This is a traditional point of view for invertebrate paleontology. We concur with Knight that this is responsible, as much as anything, for the lack of mature growth of this branch of paleontology. As a result geology and biology have both been cheated through the traditional adherence to limited objectives in studies of invertebrate fossils. Would one say that paleoecology, studies of phylogenies, restoration of life of the past, and similar objectives are comprehended in stratigraphic paleontology? If so these are included in stratigraphic paleontology in theory only, as demonstrated by the history of the science. These biologic objectives simply cannot be attained by scientists whose training fits them mainly for the study of rock strata.

As a logical conclusion from his premises Weller goes on to say that "any student of fossils who does not have a strong, abiding and well founded interest in geology and a thorough training in the science is not a paleontologist. He is simply a paleobiologist." (Op. cit., p. 572.) This statement is dangerously misleading and it reflects a prevalent myopic view of the scope of paleontology. We would rephrase Weller's statement thus: any student of fossils who does not have a strong, abiding and well founded interest in making the most of his fossils by interpreting them fully in the light of the amassed facts and philosophies of modern biology, and as well through a thorough use of the principles and techniques of stratigraphy, falls far short of the broadest objectives of paleontology.

Possibly Professor Weller had in mind stratigraphic geology, where he uses the term 'geology' in the above quotation, but he does not say so. No student can hope to obtain thorough training any more in all branches of geology in a 7-year university course, much less depth of training in related basic sciences. We do not believe that stratigraphic geology is synonymous with geology, broad as that field has become. We are not acquainted with any stratigrapher who has really mastered all of the related fields of physical stratigraphy, tectonics, regional geology, sedimentation, and stratigraphic paleontology, much less the remainder of geology. It is probable that the majority of leading stratigraphers have now given up pretensions to paleontology, a trend largely due to a bias toward the physical sciences in geology curricula.

This bias is revealed, perhaps unconsciously, in Weller's remark that "paleontology, in its broader aspects, is not a branch of biology." With this we agree, but if paleontology is not a branch of biology, neither

is it a branch of geology, as he has so categorically stated. It is a field of learning intermediate between biology and geology, and any paleontologist who loses sight of this fact will in consequence be biased toward the one larger scientific discipline or the other. And in so far as he does show a strong bias either toward geology or biology, he ceases to be a well-balanced paleontologist. To sum it up, paleontology is not a branch of either biology or geology, it is paleontology.

Professor Weller confesses the urgent need for more biology in the training of paleontologists, but he would not sacrifice any geology course for biology. This he makes clear where he states that "biological training cannot be simply substituted for an equivalent amount of geology in the curriculum." (Op. cit., p. 574.) Thus even courses which have no immediate contact with paleontology would be required, even at the expense of fundamental biology courses. Are not fossils biological objects? Weller writes as though he is not sure. He says "in fact I think that a very respectable paleontology would be possible even if there were no store of scientific biologic knowledge to be drawn upon." (Op. cit., p. 572.) This is a most extraordinary statement coming from a scientist who has distinguished himself by excellent paleobiological studies amongst other things. There is no group of fossil animals or plants, extinct or otherwise, which is not generally understood and interpreted in terms of living forms. That most fascinating story of the past, historical geology, is alive and meaningful by virtue of application of biological knowledge to fossil remains. We suspect that what Weller means in the above quotation is: a very useful stratigraphic paleontology would be possible even if there were no store of scientific biologic knowledge to be drawn upon. William Smith learned about applied paleontology long before Darwin's day, even though most of the "usefulness" of fossils is based on the fact of organic evolution.

Professor Weller regards "paleontologist" as a more inclusive category than "paleobiologist." Were it not for the two aims in paleontology, the geologic and biologic, there would be no need for more than a single term, nor excuse for the confusion which results from multiplicity of terms. Since the geological aim is supposed to be the only objective of interest to geologists, and since Weller is a geologist the term paleontology is regarded by him as a branch of geology, whereas paleobiology is employed for those supposedly less useful branches of paleontology which emphasize the organic nature of paleontologic materials. This is typical of the lack of understanding on the part of the physical scientist of the scope of biological science. *Biology, hence also paleobiology, is concerned with a complete understanding of organisms.* Obviously this objective includes accurate and detailed studies of correlation of pertinent strata and their succession as indispensable basic data. These are not in themselves viewed as significant ends, however, but are applied to studies of evolution, which in its broad aspects includes phylogeny, geographic differentiation, and paleoecology. The study of fossils as organisms, instead of simply as horizon markers, thus has a biologic bias, but it also involves all of the stratigraphic knowledge and techniques that exist. Here is the difference between the development of basic science, and the use of it as a tool. From the beginning stratigraphic paleontology has been a technology concerned with the uses of fossils. The discovery of new guide fossils, and their uses in correlation may be basic to stratigraphy, but they certainly are not fundamental paleontology, which is the study of fossil organisms not the study of rocks.

Yet Professor Weller would seem to regard the stratigraphic contributions of paleontology as the most fundamental part of the subject. For instance, "Paleontology contributes to stratigraphy, and therefore to geology as a whole in two ways. First, it makes correlation possible and, second, it furnishes information concerning environments of sedimentary deposition that could be gained in no other way." (Op. cit., p. 573.) This statement, it seems to us, illustrates very nicely a fundamental concept among many invertebrate paleontologists that has led to the present strictures on this field of learning. Many students of invertebrate fossils have been interested not so much in their fossils as in how they could apply their knowledge of these fossils to problems of geology. Thus, invertebrate

paleontology has come to assume a secondary role in their minds, so that they think not as students of past life but rather as students of rocks, to whom the fossils enclosed within the rocks are convenient objects that aid in deciphering various geologic problems. It is this attitude against which one of us has made a previous protest.[4]

As set forth in the published complaint cited above, the invertebrate paleontologist in North America has suffered because of his lack of an *evolutionary* viewpoint, the result of a lack of training in biology. This is one of the great reasons why the study of invertebrate paleontology as a dynamic science has lagged so far behind the study of fossil vertebrates during the past few decades. Professor Weller may complain about certain vertebrate paleontologists who have "handled unskillfully geological problems that have arisen in connection with their studies and were essential to them." (Op. cit., p. 573.) But the vertebrate paleontologist, who is primarily interested in the evolutionary aspects of his subject, can complain with much feeling about the almost complete ignorance of modern evolutionary concepts that marks the pedestrian work of many invertebrate paleontologists. And while the studies of the vertebrate paleontologist "have certainly been of relatively much less service to geology" (Op. cit., p. 573) than those of his invertebrate colleague, they have been of inestimably more value to our present knowledge of organic evolution. And should not the study of organic evolution be much nearer to the primary aim of any paleontologist than "service to geology?"

In conclusion: (1) Paleontology is an intermediate field between geology and biology; it shares both of the latter. It is absurd to call it geology or biology, since it is both. For utilitarian reasons geology has found invertebrate paleontology indispensable, hence, geology departments have assumed responsibility for the development of invertebrate paleontology. Vertebrate paleontology, and paleobotany also have a utilitarian aspect, but require as a minimum a much more extensive biological training, hence traditionally these fields have been developed with a strong biological bias.

(2) Paleontology may conveniently be classed as basic (paleobiology) and applied (stratigraphic), to give emphasis to the unlimited versus the limited objectives of the two divisions of the subject. The broadest objectives should be a complete understanding of all paleontological materials in all of their aspects.

(3) Paleontology requires a comprehensive training in biology and in addition a parallel training in practical stratigraphy. Naturally, "thorough training" of a student in both geology and biology is not possible because of the vastness of the combined knowledge in the two subjects. It is necessary, therefore to recognize the fact that the paleontologist is neither a biologist alone nor a geologist alone, and to adjust his training accordingly. He must be trained as a paleontologist, in order that he will have the mental outlook of a paleontologist; in other words of a man interested in the *study of fossils*.

[4] Colbert, Edwin H., Functions of Vertebrate Paleontology in the Earth Sciences. Bull. Geol. Soc. Amer., vol. 58, pp. 287–292, 1947.

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# PALEONTOLOGIST—BIOLOGIST AND GEOLOGIST

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THE PRECEDING article by Newell and Colbert "Paleontologist—Biologist or Geologist?" is an excellent exposition of the nature and objectives of paleontology. I agree with them heartily in many respects. They have, however, seriously misunderstood some of my views and misinterpreted some of my statements in spite of an exchange of personal correspondence which I had hoped would rectify these matters.

As my previous title[1] implies, I sought primarily to point out the very close relations that connect paleontology to geology and expressed the opinion that separation would be a disservice to both, but continued by criticising the present trends of invertebrate paleontology. This last has been almost completely ignored by Newell and Colbert although it should make clear that I am as fully aware as they of the gross neglect of fundamental biological problems by invertebrate paleontologists.

Part of our seeming differences are matters of definition. Because I think of paleontology as a branch of geology, I naturally think of myself as a geologist. The conclusion does not necessarily follow, as erroneously assumed by Newell and Colbert, that I, or any other "geologist," must be blind to, or uninterested in, the purely biologic aspects of paleontology. Also they use "paleobiologist" with what seems to be exactly the same meaning as my "paleontologist." To me a paleobiologist is a student of fossils without an interest in geology[2] while they wrongly assume that my "paleontologist" implies one lacking in biologic interests.

The attitude assumed by Newell and Colbert, that paleontology is an end in itself, is the traditional attitude of the "pure" scientist. They recognize that paleontology is useful to geology but apparently do not consider this to be of any particular importance. I believe this to be a narrow minded view.

As Newell and Colbert point out, paleontology can be divided into two parts: "basic" paleobiology and stratigraphic paleontology which I believe are of equal importance, but should be listed in reverse order. There is no doubt that the former has been neglected by invertebrate students. This is an indication of immaturity and the unbalance should be corrected. However, without the data furnished by stratigraphic paleontology there could be no fundamental paleobiology. The correction of this situation requires an increase in emphasis in one direction, not a decrease in the other as Knight and Newell and Colbert seem to suggest.

Furthermore, paleontologists *must* assume responsibility for the application of paleontology to geology in the field that may be termed bio-stratigraphy. This is imperative because geologists without sound paleontologic training are not qualified to do so. Thus paleontology as a whole is indebted to stratigraphic paleontology for much of its basic data and is obligated to make a return by aiding the advancement of bio-stratigraphy. Any movement to divorce paleontology from geology is detrimental to both because this very close circular relationship which both begins and ends with stratigraphy would almost certainly be weakened or broken. There is no similar relationship connecting paleontology with biology.

Obviously the ideal paleontologist is one who is well trained in biologic thinking and geologic practice. Only he can hope to realize the objectives of paleontology. It is much easier, in my opinion, to acquire biologic thinking than geologic practice and it is both logical and advantageous for paleontology to continue as a branch of geology.

The reasons given by Knight and by Newell and Colbert for neglect of the biologic aspects of paleontology within departments of

[1] Relations of the Invertebrate Paleontologist to Geology. Jour. Paleontology, vol. 21, 1947, pp. 570–575.

[2] Because of my belief that stratigraphy is "the heart of geology," my use of the word geology or its derivatives here implies stratigraphy plus the concepts, principles and practices of other closely related geologic fields.

geology are largely true but there is no reason why such neglect must continue within a progressive department. It seems to me that the desire to set up paleontology as a separate science suggests a professional inferiority complex. So separated it would be given the superficial appearance of greater importance without adding one whit to the scope of its field or making possible any additional accomplishment.

Whether or not paleontology is considered a branch of geology is unimportant, but it is important that a close connection be maintained. It is also important, however, that paleontologists be soundly trained in biology.

I wish to take this opportunity to state regret for my unfortunate observation that "paleobotany is stagnating in America today" (p. 575). A paleobotanist friend informs me that there are more active workers in this field here now than ever before and that the Paleobotanical Section of the American Botanical Society is the only paleobotanical organization in the world. I also regret, however, that current paleobotanical studies are so predominantly botanical that they are practically unknown to geologists. By losing contact with geology paleobotanists are probably missing important opportunities and are not performing an important function that must be their responsibility. A similar situation would probably result were invertebrate paleontology divorced from geology.

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# REVIEW

PRINCIPLES OF MICROPALEONTOLOGY, by Martin F. Glaessner. New York: John Wiley and Sons, 1947 (U. S. edition). Pp. xvi+296, figs. 64, tables 7, pls. 14. $6.00.

The American edition of this work, which was originally published in Australia in 1945, has now appeared and should prove extremely useful to micropaleontologists and particularly to students. As the name suggests, it reviews the entire specialized field of micropaleontology and includes much practical information not readily available elsewhere. The subject matter is presented in three parts and an Appendix.

Part I begins with a brief introductory chapter on the origin and present status of micropaleontology and continues with a classification and brief review of microfossils other than Foraminifera. This is the only special consideration given to the other fossils, and some parts are much too brief. For example, less than five pages are devoted to ostracodes and less than three pages (exclusive of text figures) to conodonts and scolecodonts combined. This part is concluded by a chapter on collecting, preparing, and studying microfossils, which is excellent.

Part II, devoted to the Foraminifera, constitutes about half the book. It begins with accounts of the life history and general morphology of these organisms, which are well organized, up to date, and, at the same time, brief but complete. The next chapter (over 100 pp.) is concerned with classification. The principles of classification are clearly explained, and previous classifications are compared. Then follows a systematic account of nearly 300 genera and subgenera arranged in 37 families. This section is very similar to the presentation of like material in Cushman's and in Galloway's well known works but is less complete. Glaessner's classification in general follows Cushman's but is somewhat simplified and considerably altered in parts. A noteworthy feature is the grouping of families in 7 superfamilies whose presumed phylogenies are discussed. Generic descriptions are brief but clear and adequate. The type species and stratigraphic range of each is given. Of particular importance are the excellent illustrated explanations of structural complexities which characterize certain groups. Unfortunately, this section as a whole is inadequately illustrated, and there are no cross-references between eight plates of Foraminifera and the text. A compensating feature, however, is a series of extremely useful tables which contrast the main morphological characters of more than 100 of the more important genera arranged by families. This part is concluded by a chapter on the paleoecology of both benthonic and pelagic Foraminifera.

The third part begins with a summary of the known stratigraphic occurrences of all types of microfossils and is continued by a chapter on the principles and application of stratigraphic correlation with special reference to microfossils and by another on the application of micropaleontology to petroleum exploration in various parts of the eastern hemisphere. The latter appears to be out of place in this book and is so general that it has little importance except for the presentation of some little-known historical facts and a very broad and incomplete tracing of certain contemporaneous ecological zones. Finally, a short chapter is devoted to a list of equipment needed by micropaleontologists and the suggested layout of a laboratory. This is much more closely related to the last chapter of Part I than to the foregoing portions of Part III.

The Appendix consists of a tabular synopsis of Glaessner's classification of the Foraminifera, with the stratigraphic range of each genus and the so-called "larger" Foraminifera distinguished; a table showing the equivalency of his families to Cushman's; and a bibliography of 30 pages arranged by subjects according to chapters in the text. Separate indexes are provided for subjects discussed, fossils mentioned or described, and authors to whom reference is made. The volume is concluded with a table showing the standard European stratigraphic scale.

This book is obviously the work of a practical micropaleontologist of wide experi-

ence. Some of the more general sections, like those on ecology and the principles of classification and stratigraphic correlation, reflect a sensible modern viewpoint and an understanding of the essential biological background of paleontology. Their application is not bounded by the limits of micropaleontology.

This book is less a handbook or reference work than is either Cushman's or Galloway's volume. With some supplementing of the nonforaminiferal microfossils, it will serve admirably as a very practical textbook of micropaleontology.

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FIG. 30.—Cerro Bernal, volcanic plug. (Reproduction of sketch by Captain G. F. Lyon, 1828; redrawn by F. S. Howell.)


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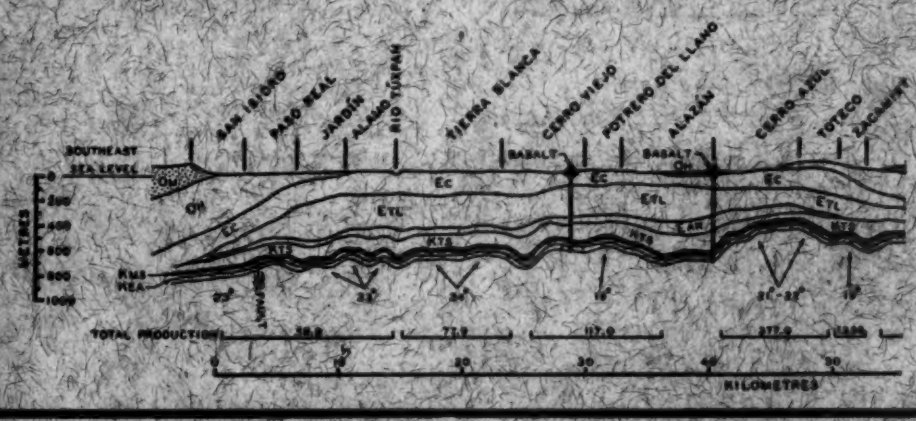



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